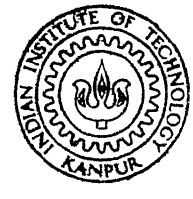
# A QUERY LANGUAGE FOR THE RELATIONAL DATA BASE

By

VINOD GUPTA






COMPUTER SCIENCE PROGRAMME

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# A QUERY LANGUAGE FOR THE RELATIONAL DATA BASE

A Thesis Submitted
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CERTIFICATE

This is certified that the work entitled, 'A QUERY LANGUAGE FOR THE RELATIONAL DATA BASE' has been carried out under my supervision by Shri Vinod Gupta and it has not been submitted elsewhere for a degree.

(V. Rajaraman)
Professor of Computer Sciences
Indian Institute of Technology,
Kanpur

July 11, 1980

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Vinod Gupta

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## ABSTRACT

This thesis suggests a new 'Query Language' for information retrieval from a Relational Data Model. It also shows the implementability of the language. All the system programs have been written in PASCAL, because of the excellent character manipulation capabilities of the language. The system has been successfully implemented on DEC 1090 System available in the Computer Centre of Indian Institute of Technology, Kanpur.

# CHAPTER I

# INTRODUCTION

## 1.1 Data Base Management System:

DATA, as usually conceived of, is some collection of information, gathered from somewhere, with some intentions - may be clearly defined but not usually so. If allowed to remain in its crudest form, the data is of no practical use to anyone, even if the purpose for which it was collected was well defined. It has to be converted to a form such that it can be comprehended, partly if not wholly, by anybody who wants to make use of it. By converting it to some such form and storing it, may be in the secondary memory of a computer, one is moving towards, what we call as 'building a data base'. But a lot more needs to be done. How to get the desired information out of this stored structure like magnetic disk or tape? Some methodology has to be adopted for the purpose. This methodology, technically known as 'Data Base Management System', should be such that a user can construct his own 'information need statements' and interrogate the data base without having much knowledge of the system. Of course, he is expected to know what data is stored in the system which he wishes to interrogate. (Otherwise what is he looking for anyway).

The user of a data base could be anyone. For example, in an industrial organization, he could be anyone right from the foreman at the shop floor level to the top managers of the organization. Each of these persons has a different way of thinking and expressing his needs. Whereas a computer system, like the DBMS, requires constructs in a very formal language before it can cater to the needs of the user.

1.2 Motivation:

In this thesis, an attempt has been made at describing a new language which enables one to construct queries to interrogate a Relational Data Base. The statements in the language are such that, with the knowledge of the syntax of the language, they come naturally from the word statement of the query. The idea is taken from 'Decision Tables' because it is felt that any query can be naturally split into two parts - a condition part and an action part. Moreover, the concept of a decision table is easy to understand.

A Relational model has been chosen for the data base because of its undoubted conceptual superiority over the other models like the Network model and the Hierarchical model. It is assumed that the relations stored in the data base are in the Third Normal Form.

The motivation behind this work has come from the fact that, in general, the user of any data base will not be a computer professional. Any occasional user (of a probably

large data base) must be able to satisfy his information need without having to hire a computer professional for the purpose. In other words, this thesis suggests a Higher Level Language with the idea that the user will find it easy to program his queries in this language. It also makes an attempt at showing that the language is complete and it can be implemented on any of the present day big computer systems. Examples have been taken from Codd's paper [4] to show that the language can retrieve information for all sorts of complex but meaningful queries.

## 1.3 Organization of the Thesis:

After a brief introduction in Chapter I, a study of the present relational data base systems has been done in Chapter II. Chapter III describes the new proposed language. It shows how the different constructs have been developed and gives the full syntax details of the language. Chapter IV is devoted to the implementation details, which include processing of queries in the language and converting them to the relational algebra expressions. Algorithms for implementing the different relational algebra operations have been given in Chapter V. The concluding chapter summarizes the work done and indicates the scope for improving the system.

# CHAPTER II

# PRESENT STATE OF ART

## 2.1 The 'Relational Model':

The relational model of data base was introduced by E.F. Codd of the IBM Research Laboratories in 1970. He was particularly interested in providing the user of the data with a data model which would be independent of the various implementation considerations. He was also interested in making available to the user a high-level language, which would be non-procedural in nature, for accessing the data. In his first paper (ref. [6]) he says that,

'The relational model of data provides a means of describing data with its natural structure only - that is without superimposing any additional structures for machine representation purposes. Accordingly, it provides a basis for high-level data language which will yield maximal independence between programs on the one hand and machine representation and organization on the other. A further advantage of th relational view is that it forms a sound basis for treating derivability, redundancy and consistency of relations'.

A relation is defined in mathematics as follows: Given sets D1, D2, ... Dn (not necessarily distinct), R is a relation on these n sets if it is a set of ordered n-tuples d1,d2,...dn such that d1 belongs to D1, d2 belongs to D2, and so on.

Sets D1, D2,...Dn are called the domains of R. The value n is called the degree of R.

It is convenient to represent a relation in the form of a table, where each row represents one n-tuple. The relation 'Part' shown in Figure 2.1 consists of 6 tuples.

Fig. 2.1: A typical relation.

PART

| P # | PNAME | COLOR | WEIGHT | QOH |
|---|---|---|---|---|
| 1 | NUT | RED | 12 | 4 |
| 2 | BOLT | GREEN | 17 | 7 |
| 3 | SCREW | BLUE | 17 | 3 |
| 4 | SCREW | RED | 14 | 9 |
| 5 | CAM | BLUE | 12 | 2 |
| 6 | COG | RED | 19 | 1 |

It is observed that a relation has the following properties:

(1) No two rows are identical,

(2) Ordering of rows is insignificant,

(3) Ordering of columns is also insignificant,

(4) Every value within a relation is an atomic data item.

The last property is true in case the relation is in the 'Third Normal Form' (Ref. [5]).

It was pointed out by Codd that the relational operations defined in mathematics can be applied on these relations. He

showed how to carry out the operations like projection and join on these relations.

Most existing systems are not relational as a natural outcome of the way in which computing technology has itself developed. The earlier computer systems had comparatively small capacity and high access time. Traditionally, the emphasis was on sequential media like tapes and cards. With modern hardware and techniques, it has become possible to design and implement more large scale systems based on the relational approach.

## 2.2 Data Sub Languages for the Relational Model:

For query purposes in a relational model, a data sub language (DSL) should allow the user to specify the relation he wants retrieved from the data base. It is to be pointed out here that any information that a user obtains from the data base will be in the form of a new relation which will be derived from the original relations stored in the system. There are two ways in which a user can specify the new relation he wants retrieved from the data base -

(1) A non-procedural method, in which he would simply state the definition of the desired result and leave it to the system to determine the required operations.

(2) A procedural method, in which he would actually specify the step-by-step operations to be performed to produce the

desired result. (The operations here refer to the relational operations - join, project and divide).

2.2.1 Codd's DSL ALPHA is a non procedural (calculus based) language. It is data independent in that it contains absolutely no references to storage/access details such as indexes, pointers etc. The language is complete. The complexity of a statement in DSL ALPHA is in direct proportion to the complexity of the operation the user is trying to perform.

2.2.2 A procedural language (algebra based) also provides full data independence. It is a reasonably simple language but probably less simple than DSL ALPHA. Compared to most existing languages, which tend to be very low level, the algebraic language can be called to be non-procedural. But compared to DSL ALPHA it is definitely more procedural.

2.2.3 As an illustration of the types of statements in the two languages mentioned above, let us take the following query based on the relations given in Fig. 3.1.

Word Statement of query:

Find the part names of parts supplied by supplier 'Jones'.

The query as converted to one in relational algebra:

JOIN SUPPLIER AND SUPPLY (over S# );

JOIN the result and PART (over P# );

PROJECT the result by PNAME where SNAME = 'Jones'.

The query as converted to one in relational calculus:

GET W P.PNAME : ∃ SUPPLY((PART.P# = SUPPLY.P#)

∧ (SUPPLY.S# = SUPPLIER.S#)

∧ (SUPPLIER.SNAME = 'JONES')).

For the sake of simplicity it is essential that the language made available to the user be non-procedural. The DSL ALPHA would be a good candidate for the same. But writing queries in DSL ALPHA requires the knowledge of 'first order predicate calculus'. Symbols like '∃' (there exists), '∀' (for all) and ':' (such that) tend to scare away the user of this language.

2.3 Existing Systems:

There have been quite a lot of small relational systems in the recent past. But most of them do not insist on any particular level of normalization. They are content with the relations being in the First Normal Form. Obviously a data model in the 1NF can not exploit most of the potentialities of a relational data base.

2.3.1 MacAIMS appears to be the earliest example (1970-71) of a system providing both a full relational model and a language (based on algebra) which actually views the data in its relational form. The language, however, is not complete, in the sense that not all relations derivable from the data model by means of first order predicate can be retrieved in this language. One interesting feature about

MacAIMS is that the structure may vary from relation to relation (thus allowing each relation to be stored in the form most suited to it). For details of the language refer to [8].

2.3.2 MORIS (1972) incorporates some of the ideas of MacAIMS. In it, however, the user's view of the data may include unnormalized relations, which are defined in terms of the fundamental normalized relations in the data model. Thus the user is provided with a limited form of data sub-model. Though the language is based on relational calculus, yet it is (also) possible to perform a retrieval using algebraic operations. For further details refer [9].

2.3.3 The IS/1 system (1972) also provides a limited form of data submodel. An 'implied relationship' is defined by a set of (algebraic) statements of this language which specify how other relations are to joined, projected, and otherwise manipulated to produce the required result. The first time the user refers to this relation, the definition is invoked and the desired relation is generated. Subsequent operations are performed directly on the generated relations. This system developed some useful optimization techniques for evaluating algebraic expressions. For further details of this language refer to [10].

2.3.4 The SEQUEL prototype was originally developed as a single user system to demonstrate the feasibility of supporting the SEQUEL language (1974). This language is complete in

the sense that any relation, derivable from the data model by means of first order predicate, can be derived in this language. It does not involve symbolism of the predicate calculus (i.e., there are no quantifiers). It is based on a construct known as 'mapping' which may be viewed as a subsetting followed by a projection. Its syntax is quite English-like. As an example the query above may be written as

```
SELECT PNAME FROM PART
WHERE P# =
      SELECT P# FROM SUPPLY
      WHERE S# =
            SELECT S# FROM SUPPLIER
            WHERE SNAME = 'JONES'.
```

However, this system has been extended by the IBM Cambridge Scientific Centre and the MIT Solan School Energy Laboratory to allow a single type of concurrency and is being used as a component of the Generalized Management Information System (GMIS) being developed at MIT for energy related applications For further details on the language refer to [7] and [11].

Of the systems given above, MacAIMS is not complete and MORIS and IS/1 present to the user a data submodel which has unnormalized relations. SEQUEL is a language which is complete and without quantifiers. But the ideas of 'mapping' and 'recursion', which are made use of in this language, are not very simple to grasp by an ordinary user. Most of the

languages of the type SEQUEL, though avoid the use of quantifiers of the relational calculus, require the user to evolve a method of generating the output relation. Like in the above example, where the constraint is on the supplier name and the attribute required in the output relation is partname, the SEQUEL query clearly specifies how the 'SUPPLY' relation is to be used to reach the 'PART' relation starting from the 'SUPPLIER' relation.

The language we are looking for should be reasonably complete (equivalent to DSI ALPHA) and should also not make use of any quantifiers. Apart from this, it should not involve any difficult concepts. As in the above example, we should not expect the user to know how the path is to be traced while executing his query. If need be, he should be expected to know only this much that the relation 'SUPPLY' will be involved in getting for him the output relation he requires, and not how it has to be used.

# CHAPTER III

## FORMULATION OF LANGUAGE

The basic idea behind specifying this language is that a query can be split into a condition part and an action part. Then it should be possible to enumerate all the possible types of conditions and actions. Finally it should be possible to combine those types of conditions and actions which require the same type of manipulations on the relations.

### 3.1 Parts of a Query:

First we show that any query can be split into a condition and action. Then we go on to studying these two parts separately. Let us start with considering a few examples (refer to the relations in Fig. 3.1).

Query Find the part name and quantity-on-hand of parts whose quantity-on-hand is less than 5.

Clearly the condition on all tuples in the output relation is that the quantity-on-hand for the part be less than 5. There is no other constraint that one can obviously see. The action part is that it is required to get into th workspace the part names and the quantities-on-hand. Thus the query can be written as -

Supplier

| S# | SNAME | LOC |
|---|---|---|
| 1 | SMITH | LONDON |
| 2 | JONES | PARIS |
| 3 | JAKE | PARIS |
| 4 | CLARK | LONDON |
| 5 | ADAMS | ATHENS |

Part

| P# | PNAME | COLOR | WEIGHT | QOH |
|---|---|---|---|---|
| 1 | NUT | RED | 12 | 4 |
| 2 | BOLT | GREEN | 17 | 7 |
| 3 | SCREW | BLUE | 17 | 3 |
| 4 | SCREW | RED | 14 | 9 |
| 5 | CAM | BLUE | 12 | 2 |
| 6 | COG | RED | 19 | 1 |

Job

| J# | JNAME | MGR-E# |
|---|---|---|
| 1 | SORTER | 24 |
| 2 | PUNCH | 11 |
| 3 | READER | 17 |
| 4 | CONSOLE | 9 |
| 5 | COLLATOR | 27 |
| 6 | TERMINAL | 18 |
| 7 | TAPE | 13 |

Supply

| S# | P# | J# | QTY |
|---|---|---|---|
| 1 | 1 | 1 | 2 |
| 1 | 1 | 4 | 7 |
| 2 | 3 | 1 | 4 |
| 2 | 3 | 2 | 2 |
| 2 | 3 | 3 | 2 |
| 2 | 3 | 4 | 5 |
| 2 | 3 | 5 | 6 |
| 2 | 3 | 6 | 4 |
| 2 | 3 | 7 | 8 |
| 2 | 5 | 2 | 1 |
| 3 | 3 | 1 | 2 |
| 3 | 4 | 2 | 5 |
| 3 | 6 | 3 | 3 |
| 3 | 6 | 7 | 3 |
| 5 | 2 | 2 | 2 |
| 5 | 2 | 4 | 1 |
| 5 | 5 | 5 | 5 |
| 5 | 5 | 7 | 1 |
| 5 | 6 | 2 | 2 |

Figure 3.1 Relations in the Data Base

Condition: Quantity-on-hand of part less than 5.

Action: Get part name and quantity-on-hand into the work space.

Let us look at another example

Query Find the names and locations of all suppliers, each of whom supplies all jobs.

The condition here is that all the jobs be supplied. By all jobs it means that the jobs, listed in the relation JOB, be treated as one entity. The action required is to get into the workspace the names and locations of suppliers. Thus the query can be written as:

Condition: All jobs.

Action: Get into the workspace, name and location of suppliers.

Let us go on to look at another slightly complex query:

Query Find the name and location of all suppliers who supply atleast those jobs supplied by supplier 'SMITH'.

This query being slightly complicated, has to be split into two smaller queries.

Sub Query A Find the job numbers of jobs supplied by supplier 'Smith',

Sub Query B Find the name and location of suppliers who supply atleast those jobs whose job numbers are in the workspace above.

This two step query can be split into condition and action as follows:

Condition: Supplier name 'Smith'

Action: Get into workspace the job numbers supplied.

Condition: All job numbers in the above workspace.

Action: Get into the final workspace supplier names and locations.

From the three examples that we have considered, it seems that splitting a query into its condition and action components is not difficult.

3.2 Workspace:

It can be noted that the concept of workspace is important. Workspaces have the following features:

(1) They are not part of the data base itself, so that there will be no inconsistency due to the creation of redundant data.

(2) The work spaces belong to one individual user or process. so that the manipulations of data within such workspaces do not conflict with other users.

(3) A naming scheme is employed to distinguish relations and attributes within the work space from the relations and attributes in the data base.

Now we look at the condition part in more details.

3.3 Condition Part:

This is essentially the same as the predicate in DSL ALPHA. Like a predicate, a condition may consist of an expression of arbitrary complexity, formulated according to the usual rules. The permitted operators are the comparison operators '=', '< >', '>', '<', '$\geq$', '$\leq$', the Boolean operators 'OR', 'AND', and 'NOT' and of course parentheses '(' and ')' to enforce a desired order of evaluation.

The condition part of any query can be reduced to a normal form:

$$C = (C11 \text{ AND } C12 \text{ AND } \ldots \text{AND } C1N_1)$$
$$\text{OR } (C21 \text{ AND } C22 \ldots \text{ AND } C2N_2) \ldots$$
$$\text{OR } (CM1 \text{ AND } CM2 \ldots \text{ AND } CMN_M)$$

where $Cij_m$ is a simple condition with one comparison operator. The result of a general query, with the condition part as 'C', can be obtained by applying 'union' and 'intersection' operations on the results of individual queries with simple condition parts. For example, the final result for condition 'C' will be given by,

$$R = (R11 \cap R12 \ldots \cap R1N_1) \cup (R21 \cap R22 \ldots \cap R2N_2)$$
$$\ldots \cup (RM1 \cap RM2 \ldots \cap RMN_M),$$

where $Rij_m$ is the relation retrieved by a query with the (simple) condition part $Cij_m$. The system is designed for a general condition of the above type. For explanation purposes however, we will consider only queries with simple conditions.

Now let us enumerate the different types of possible conditions required to incorporate all types of queries. Here it is to be pointed out that effort has been made to include all types of conditions that are encountered in queries. But the system can be easily modified for including any further types that do not fall in any of the types that are described here. This will be evident from the structure of the system.

Given below is the list of seven different types of conditions. An example query has been given with each for explanatory purposes.

(1) The value of an attribute in a relation is equal (or unequal) to a specified value. For example -

Query 1: Get the part name and quantity-on-hand of 3 parts for which the quantity-on-hand is less than 5.

(2) The value of an attribute in a relation is equal (or unequal) to (a) the n-th largest value for that attribute in that relation; (b) the n-th smallest value for that attribute in that relation. For example -

Query 2: Find the part number and part name of parts for which quantity-on-hand is the largest.

(3) Something is required to be done for each of the values of an attribute in a particular relation. For example -

Query 3: Find in the increasing order of quantity-on-hand, the part name and quantity-on-hand of parts being supplied.

(4) In a relation, the number of tuples, with same values for some attributes and different values for some other attributes in that relation, is equal (or unequal) to a specified number. For example -

Query 4: Get the number of parts being supplied to more than two jobs.

(5) In a relation the total of an attribute, with same values for some other attributes in that relation, is equal (or unequal) to a specified value. For example -

Query 5: For those parts, for which the total quantity being supplied to a job is greater than 5, get, as a triple, part number, the job number and the total quantity of that part being supplied to that job.

(6) All the different values of an attribute in a relation are to be treated as one entity. For example -

Query 6: Get the supplier names and locations of suppliers who supply to all jobs.

(7) The value of an attribute in one relation is not present in the values of that attribute in another relation. For example -

Query 7: Get the name and location of those suppliers who do not supply to any job.

We now construct statements of the language for these conditions. It can be noted that the comparison operator for

conditions of the types 1,2,4 and 5 could be any of the six, i.e., =, < >, <, >, <=, or >=. For conditions of the type 3 and 6, only the equality (=) operator is valid and for condition of the type 7, only the 'not equal to' (< >) operator is valid. The syntax for these simple conditions is as follows-

(1) Relation name.attribute name <COND > " value" .

The condition for example Query 1 becomes -

PART.COH = " 5 "

(2) (a) Relation name.attribute name <COND > n TOP

(b) Relation name.attribute name <COND > n BOTTOM

The condition for example Query 2 becomes -

PART.COI = 1 TOP

(3) Relation name.attribute name = *

The condition for example Query 3 becomes -

SUPPLY. P # = *

(4) COUNT (relation name SAME attribute names DIFFERENT attribute names) <COND > positive integer

The condition for example Query 4 becomes -

COUNT (SUPPLY SAME P# DIFFERENT J # ) > 2

(5) TOTAL (relation name SAME attribute names:attribute name) < COND > value

The condition for example Query 5 becomes -

TOTAL (SUPPLY SAME P # , J # : QTY) > 5

(6) Relation name.attribute name = ALL

The condition for example Query 6 becomes -

JOB.J # = ALL

(7) Relation name.attribute name <> relation name.attribute name

The condition for example Query 7 becomes -

SUPPLIER.S# <> SUPPLY.S#

Here '<>' is the symbol used for 'not equal to'. The reserved words of the language are given in capital letters. <COND> refers to any of the six comparison operators.

We have considered only queries with a simple condition part. Now we give examples of two more queries which have a general condition part.

Query 8: Get the names of those suppliers who supply to job number 4 and are located in Athens.

The condition for example query 8 becomes -

SUPPLIER.LOC = " ATHENS" AND SUPPLY.J# = " 4"

Query 9: Get the names and locations of suppliers who supply a blue part or a green part.

The condition for the example query 9 becomes -

PART.COLOR = " BLUE" OR PART.COLOR = " GREEN"

3.4 Action Part:

This part of the query just indicates the domains (i.e. attribute names) to be brought into the work space. It is analogous to the 'target list' of DSL ALPHA. Apart from specifying the attribute names (qualified by the appropriate relation names) to be retrieved, it might (also) be required to do the totalling of a certain field before displaying (example Query 5) or it might be required to get the count of the number

of tuples (that satisfy the condition) in the output relation (Example Query 4). Sometimes one might want to retrieve only a limited number of tuples in the output relation instead of getting a long list (Example Query 1). At other times, one might want to have the output relation sorted according to the values of certain domains(Example Query 3). All these desired results are incorporated in the system and the syntax for the action statements is defined as follows-

GET relation name.attribute name

The action part of example Query 2 becomes -

GET PART.P# , PART.PNAME

or GET TOTAL(relation name SAME attribute names:attribute nam or any combination of the above two. It is assumed that the domain, if any, of which the totalling is required is the last in the output list. The action part of example Query 5 becomes-

GET PART.P# ,SUPPLY.J# ,TOTAL(SUPPLY SAME P# ,J# :QTY)

For getting only a limited number (n) of tuples in the output relation, the syntax is -

GET (n) .....

The action part for example Query 1 becomes -

GET (3) PART.PNAME, PART.QOH

For getting only the count of the number of tuples in the work space, the syntax is -

GET (COUNT) .....

The action part for example Query 4 becomes -

GET (COUNT) SUPPLY.P#

For getting the output in a sorted order, after ~~all~~ the output list, we add the information as follows -

GET ..... ($\frac{\text{UP}}{\text{DOWN}}$ relation name.attribute name)

The action part for exampl Query 3 becomes -

GET PART.PNAME, PART.COH (UP PART.QOH)

Here the first field in the UP/DOWN list is the major field, the next is the minor field and so on.

3.5 Complete Query:

After having defined the condition part and the action part of a query, the syntax of the complete query is as follows

Query name (Work space name)

CONDITION : condition part

ACTION : action part;

As an illustration the example Query 7 would be written as -

QUERY (W1)

CONDITION : SUPPLIER.S# <> SUPPLY.S#

ACTION : GET SUPPLIER.S# , SUPPLIER.SNAME;

In case of a multi-step query, the above three lines are repeated again except that the semicolon (;), indicating the end of the query, comes only at the end of the last subquery.

The complete syntax diagrams for the language just defined are given in Figure 3.2.

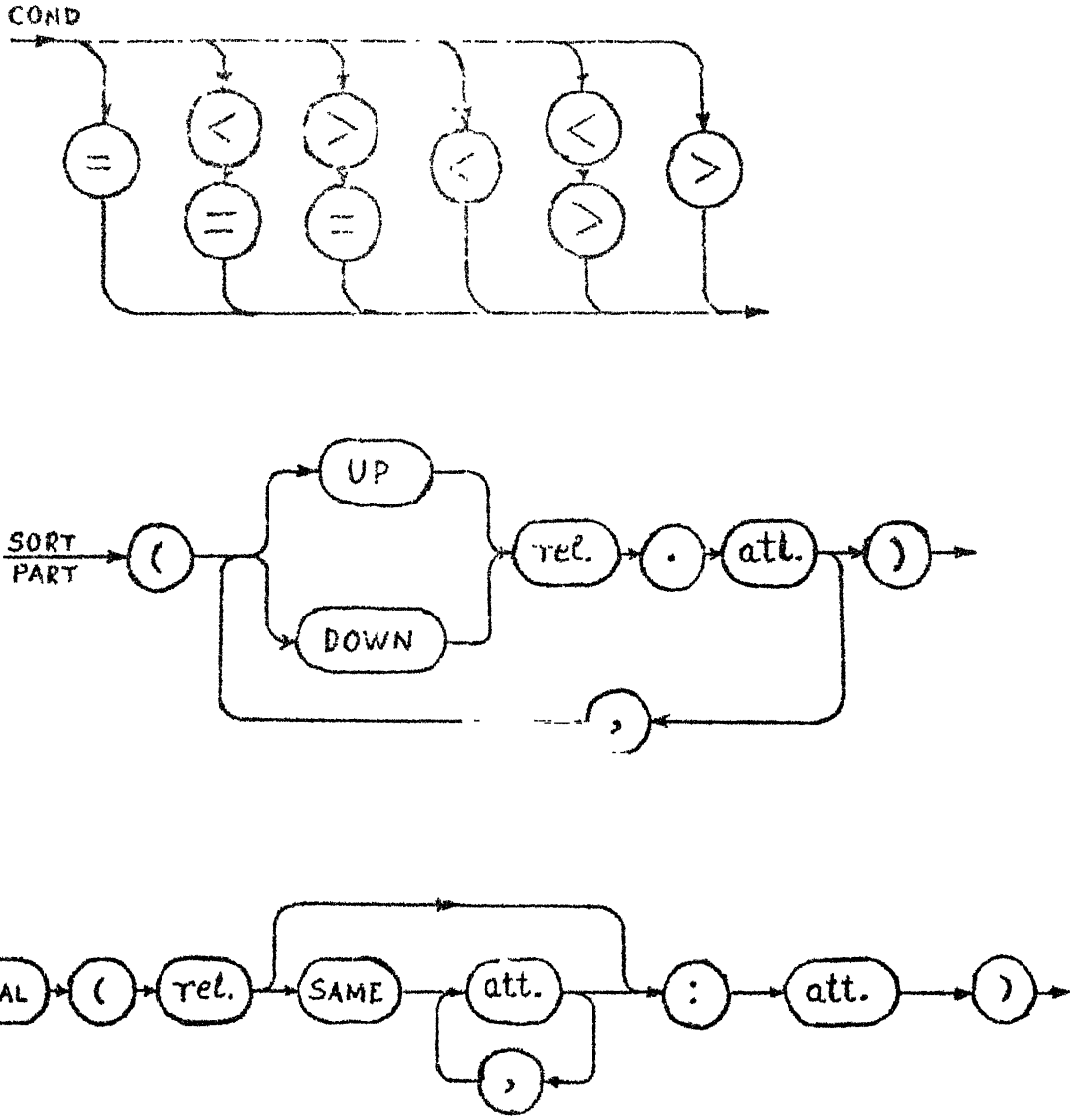
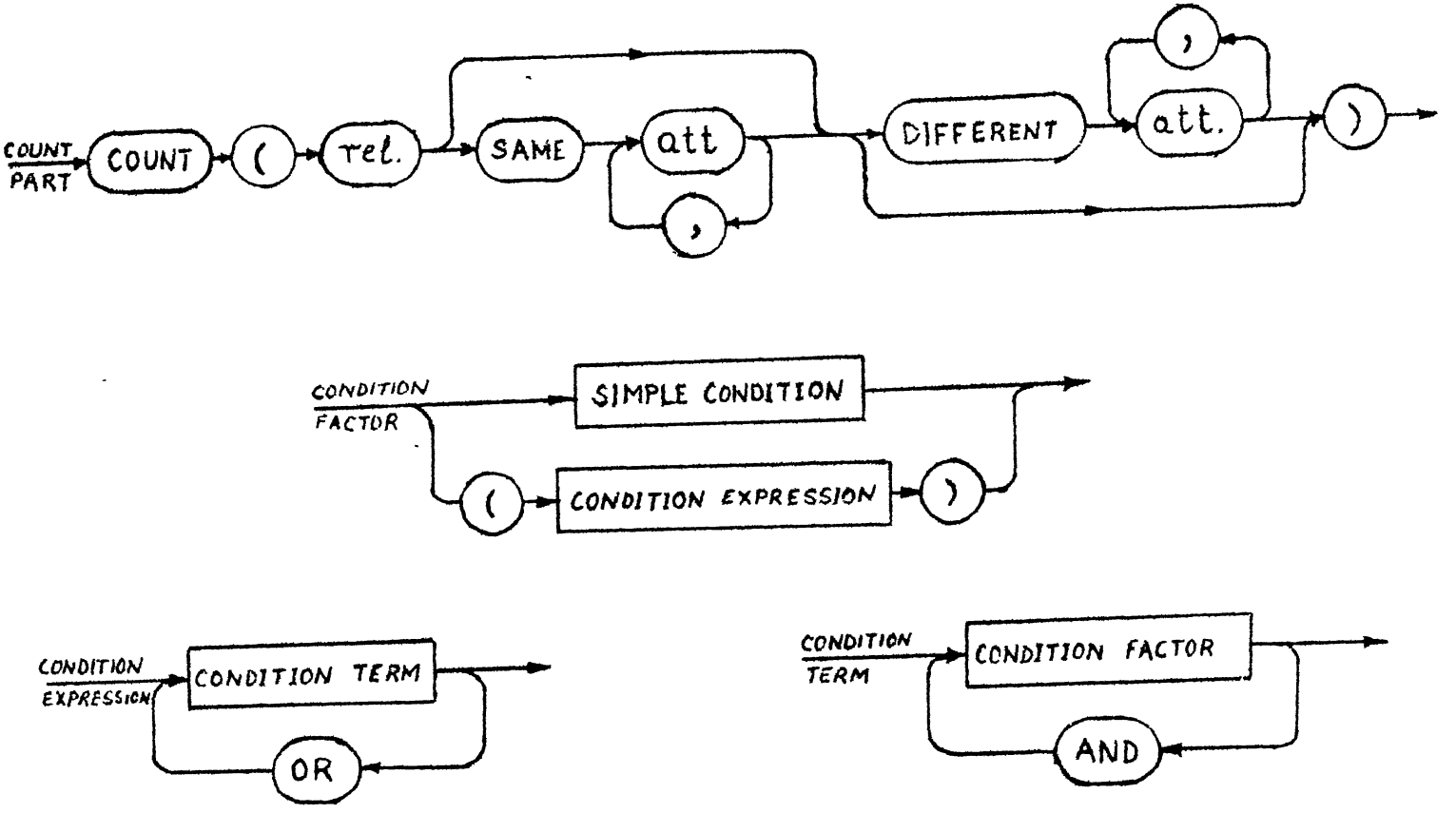



FIG. 3.2: SYNTAX DIAGRAMS OF LANGUAGE (Contd...)

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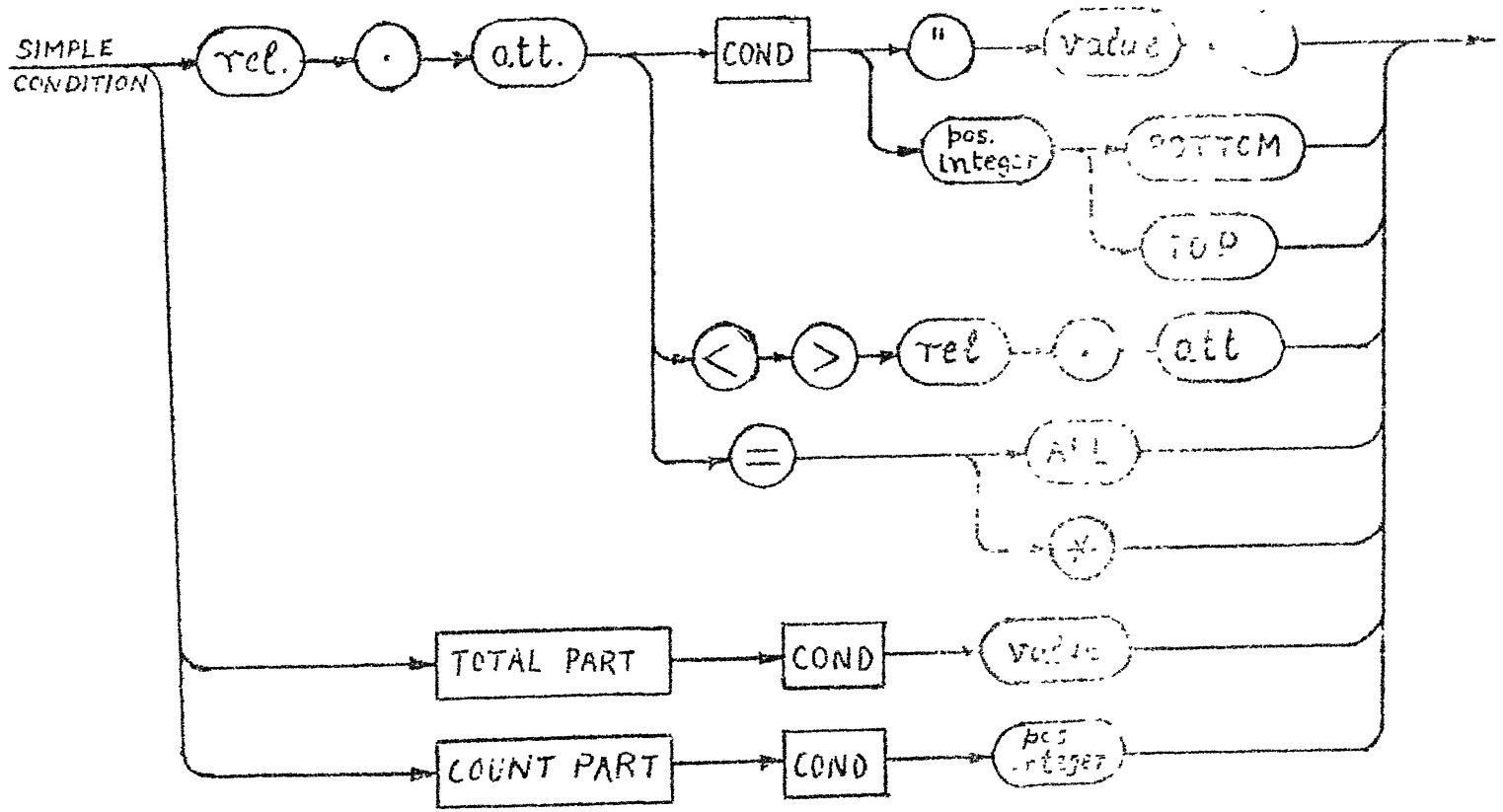
(Contd...)

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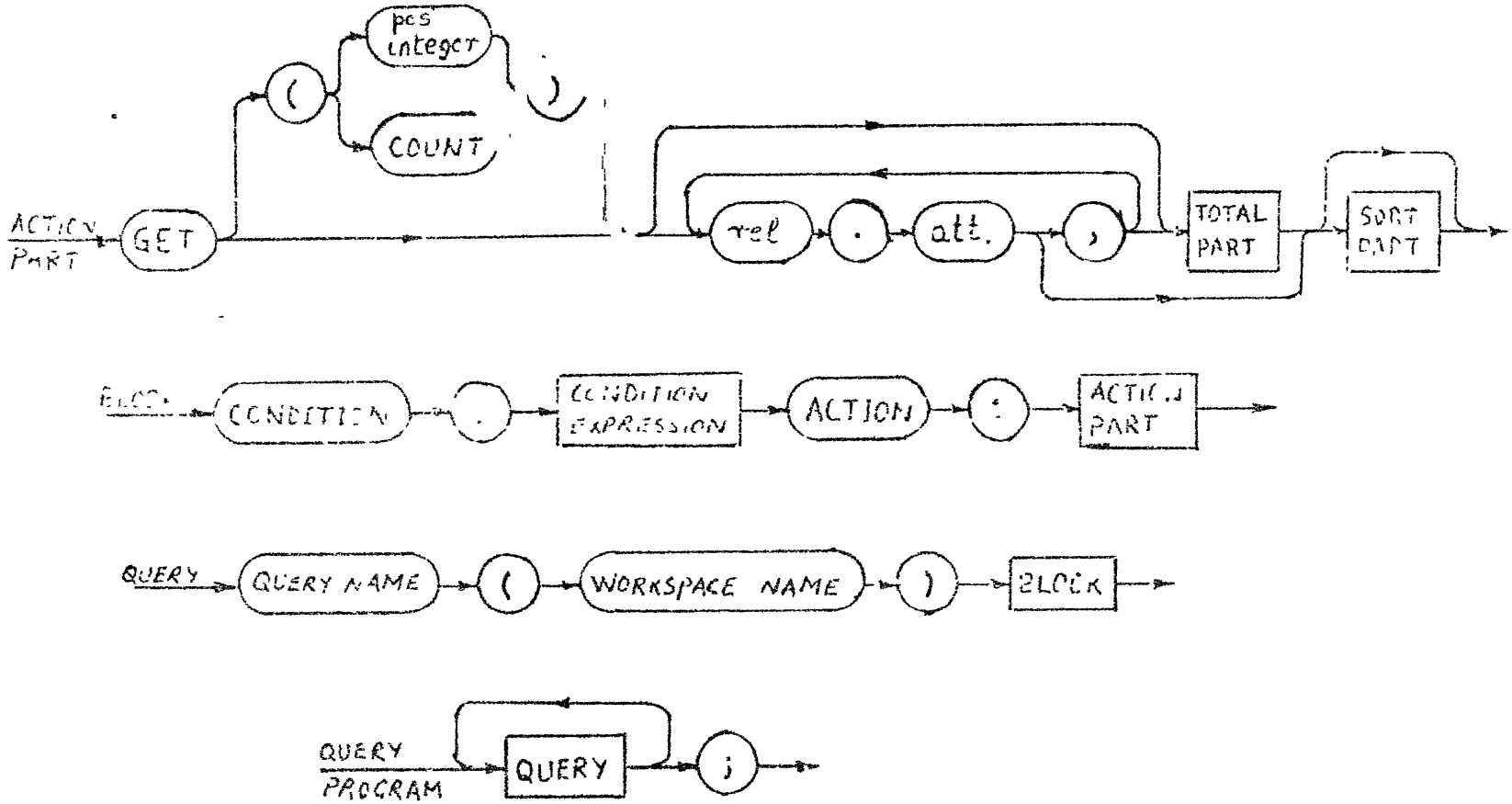


FIG. 3.2: SYNTAX DIAGRAMS OF LANGUAGE.

## 3.6 Completeness of the Language

To show that our language is reasonably complete, we will compare its features with the information retrieval features of DSL ALPHA. For each of these features of DSL ALPHA (reference [1]), we show that there exists a corresponding feature in our language which performs the same task as the one in DSL ALPHA.

(1) The concepts of 'operation name' (OPT) and 'workspace'(W) have been borrowed directly from DSL ALPHA. The user can name his own workspace and the 'name inheritance rules' of his workspace, as applicable in DSL ALPHA, are valid in our language also (Refer to example Query 10 in Chapter IV ).

(2) Corresponding to the 'target list' of DSL ALPHA we have the 'action part' in our language. The target list in DSL ALPHA contains the names of the attributes (qualified by the appropriate relation name) and so does the action part in our language. The target list can contain just a relation name, with no attributes specified, in case the whole of the relation has to be brought to the workspace. This feature is not present in our language. This does not limit the scope of our language, however, because the same purpose can be achieved by giving the complete list of attributes in that relation. (The information about the different attributes in each of the relations can be obtained from the 'RELDEF' file). Some functions which are allowed in the target list of DSL ALPHA are also

allowed in our language. Examples are 'COUNT' and 'TOTAL'. The syntax for the use of these has already been described. The functions 'MAX' and 'MIN' have not been included in the action part but the purpose can be achieved by making a multi-step query in our language. For example consider the following query in DSL ALPHA -

RANGE Z SUPPLY

GET W MAX(Z.QTY) : (Z.S# =2)

This can be converted to the following in our language -

QUERY(W1)

CONDITION: SUPPLY.S# = "2"

ACTION: GET SUPPLY.QTY

QUERY(W)

CONDITION: W1.QTY = 1 TOP

ACTION: GET W1.QTY;

(3) Corresponding to the 'qualification' in DSL ALPHA we have the 'condition part' in our language. There is a major difference, however, that the condition part is much less procedural than the qualification. A simple condition in the condition part is entirely independent of what has to come in the action part. Whereas the qualification (being a qualifier of the target list) depends upon the target list. As an example consider the following query -

Find the supplier names of those suppliers who supply the part with part number 3.

The qualification part of the DSL ALPHA statement for this query becomes

RANGE SUPPLIER S

RANGE SUPPLY Z

GET W S.SNAME : (S.S# =Z.S# ) ∧ (Z.P# = 3)

In our language the condition part will be -

QUERY (W)

CONDITION: SUPPLY.S# = "3"

ACTION: GET SUPPLIER.SNAME;

(4) The element ordering feature in DSL ALPHA is also included in our language. This expression follows the qualification in DSL ALPHA whereas it follows the action part of our language. This element ordering expression could be as general as in DSL ALPHA. (Refer to table ACTTAB described in Chapter IV).

(5) The facility of specifying the 'quota' in DSL ALPHA is also included in our language. This is done by specifying the number of tuples to be retrieved within brackets after the reserved word GET in the action part of our language. (Refer to the table ACTTAB described in Chapter IV).

(6) The negation sign (¬) used in the qualification in DSL ALPHA, though not allowed in our language, yet the purpose can be achieved by using 'not equal to' sign (<>) and the boolean operators 'AND' and 'OR' in the condition part. As an example consider the following query -

Find the supplier numbers of suppliers who do not supply part number 3 (and may not supply any part at all also).

The DSL ALPHA query for this becomes -

RANGE SUPPLIER S

RANGE SUPPLY Z ALL

GET W S.S : ¬ ((S.S# =Z.S# ) ∧ (Z.P# =3))

The query in our language for this becomes -

QUERY (W)

CONDITION: SUPPLY.S# <> "3" OR SUPPLIER.S# <> SUPPLY.S#

ACTION: GET SUPPLIER.S# ;

(7) Functions allowed in the qualification in DSL ALPHA are also allowed in our language. These functions are 'TOP' and 'BOTTOM'. The syntax for the use of these in our language has already been described.

(8) The 'RANGE' statements in DSL ALPHA, provided for the purpose of abbreviation of relation names, are not allowed in out language. They just serve the purpose of avoiding the repetition of long relation names in the query statement, and are not functional. In as far as they also serve the purpose of defining the user's data sub-model, we can provide in our language the 'ENVIRONMENT' statement (Refer to Chapter VI). In DSL ALPHA the range statements also serve the purpose of allowing the shift of the universal quantifier from the qualification to these statements. This feature has been incorporated in our language by a special condition type (CNDCD = 3 (refer Chapter IV) which specifies that all the attribute

values of an attribute in a relation be treated as one entity. For example consider the following query -

Get the supplier numbers of suppliers who supply to all jobs.

The DSL ALPHA query for this becomes -

RANGE SUPPLY Z

RANGE JOB J ALL

GET W Z.S# : (Z.J# = J.J# )

The corresponding query in our language becomes -

QUERY (W)

CONDITION : JOB J# = ALL

ACTION : GET SUPPLY.S# ;

Thus we can say that our language incorporates all the features of DSL ALPHA as described in reference [1].

# CHAPTER IV

# SOURCE QUERY TO OBJECT QUERY

## 4.1 Source Query and Object Query:

After having designed the query language, we have to build a system that accepts queries in this language and executes them. We call, for notation sake, a query in our new language as the 'Source Query' and that converted to one having relational algebra operations as 'Object Query'. Like any other language translator, the first phase of this system analyses the string of characters in the source query so as to form meaningful symbols. This phase is called 'lexical analysis'. Outcome of this phase is a string of meaningful primitives, called lexemes (like 'GET', '.', 'ALL' etc. in our language). The next phase of the system has to combine such lexemes, collected from the input string of characters, and recognize grammatical phrases in the source query. This is called 'syntax analysis'. Finally, the system has to discover how the source query does what it is supposed to do. This is the 'semantic analysis' phase. It is required to build certain tables which store information contained in the source query (about the intent and the names of relation and attributes involved). From the information stored in these tables and that already existing in the system (about various

relations and their attributes present in the data base), the object query is constructed. The object query has statements like

```
        JOIN     R1 AND R2 ON A1;
or      PROJECT  R1 BY  A1    A2;
or      SORT R1 ON ASCENDING A1 DESCENDING A2; etc.
```

Here R1, R2 are relation names, either original or those constructed by the user for storing intermediate results, and A1, A2 are attribute names.

4.2 Lexical Analysis:

The task of the lexical analyser is to recognize in the input string, which is the source query, items like names, numbers and separators. This task is done by procedure GETNEXTSYM. Whenever the syntax analyser makes a call to this procedure, the next symbol (lexeme) in the input string is passed on to the calling procedure through a global variable 'SYM'. 'GETCH' is a standard procedure which reads the input text and passes on to the calling procedure (GETNEXTSYM in this case) the next character in the string. The global variable for a character is 'CH'.

NORW, the number of reserved words in the language, is a constant and is set to 14 in the beginning of the program. These reserved words are ACTION, ALL, AND, BOTTOM, CONDITION, COUNT, DIFFERENCE, DOWN, GET, OR, SAME, TOP, TOTA

and UP. There are 11 delimiters. They are -':'(colon), '(' (lparen), ')'(rparen), '.'(period), ','(comma), ';'(semi-colon), '='(eql), '<'(lss), '>'(gtr), ''''(aspst) and '*'(star) Three other delimiters are formed by a combination of these. They are - '<>' (neq), '<='(leq) and '>= (geq). The reserved words and delimiters are initialized by procedure INITIALIZE (Fig. 4.1).

The identifiers in the language could be upto 'AL' characters in length. (AL is a constant and is set to 10 in the program). As usual, the identifiers can start with any of the alphabets ('A' to 'Z') and can contain alphabets, digits and characters '#' and '-'. These last two characters have been included because attribute names in a data base can contain such characters. (e.g. 'MGR-E#').

Numbers could be integers or floating point reals. A negative number can be represented by a '-' sign before the value, but a non-negative number should not have a '+' sign before it.

The listing of procedures GETNEXTSYM and GETCH are given in Figure 4.2.

## 4.3 Syntax Analysis:

The syntax of the source query is checked in accordance with the syntax diagrams of the language described in Chapter III It is almost a 'one look-ahead' parsing scheme. Provision has

```
procedure INITIALIZE;
  begin WORD[ 1]:='ACTION      ';
    WORD[ 2]:='ALL         ';
    WORD[ 3]:='AND         ';
    WORD[ 4]:='BOTTOM      ';
    WORD[ 5]:='CONDITION   ';
    WORD[ 6]:='COUNT       ';
    WORD[ 7]:='DIFFERENT   ';
    WORD[ 8]:='DOWN        ';
    WORD[ 9]:='GET         ';
    WORD[10]:='OR          ';
    WORD[11]:='SAME        ';
    WORD[12]:='TOP         ';
    WORD[13]:='TOTAL       ';
    WORD[14]:='UP          ';
    WSYM[ 1]:=ACTIONSYM    ;
    WSYM[ 2]:=ALLSYM       ;
    WSYM[ 3]:=ANDSYM       ;
    WSYM[ 4]:=BOTTOMSYM    ;
    WSYM[ 5]:=CONDITIONSYM ;
    WSYM[ 6]:=COUNTSYM     ;
    WSYM[ 7]:=DIFFERENTSYM ;
    WSYM[ 8]:=DOWNSYM      ;
    WSYM[ 9]:=GETSYM       ;
    WSYM[10]:=ORSYM        ;
    WSYM[11]:=SAMESYM      ;
    WSYM[12]:=TOPSYM       ;
    WSYM[13]:=TOTALSYM     ;
    WSYM[14]:=UPSYM        ;
    for CH:=CHR(0) to CHR(127) do SSYM[CH]:=NUL;
    SSYM[':']:=COLON       ;
    SSYM['(']:=LPAREN      ;
    SSYM[')']:=RPAREN      ;
    SSYM['.']:=PERIOD      ;
    SSYM[',']:=COMMA       ;
    SSYM[';']:=SEMICOLON   ;
    SSYM['=']:=EQL         ;
    SSYM['<']:=LSS         ;
    SSYM['>']:=GTR         ;
    SSYM['#']:=APST        ;
    SSYM['*']:=STAR        ;
    CC:=0;
    LL:=0;
    CH:=' ';
    KK:=AL;
    ERR:=0;
    TEMPSYM:=NUL;
    IREL:=NORELS
  end;
```

FIGURE 4.1 PROCEDURE INITIALIZE

```
procedure GETNEXTSYM;
  var
    I,J,K:integer;
  procedure GETCH;
    begin
      if CC=LL then
       begin
        if EOF(INPUT) then
         begin WRITELN('Query is incomplete.');
          HALT
         end;
        LL:=0;
        CC:=0;
        WRITE(' ');
        while not EOLN(INPUT) do
         begin LL:=LL+1;
          READ(CH);
          WRITE(CH);
          LINE[LL]:=CH
         end;
        WRITELN;
        LL:=LL+1;
        READ(LINE[LL])
       end;
      CC:=CC+1;
      CH:=LINE[CC]
    end;
  begin  while CH=' ' do GETCH;
    if CH in ['A'..'Z'] then
     begin K:=0;
      repeat
        if K<AL then
         begin K:=K+1;
          A[K]:=CH
         end;
        GETCH
      until not (CH in ['A'..'Z','0'..'9','$','-']);
      if K>=KK then KK:=K
      else
      repeat A[KK]:=' ';
        KK:=KK-1
      until KK=K;
      ID:=A;
      I:=1;
      J:=NORW;
      repeat
        K:=(I+J) div 2;
        if ID<=WORD[K] then J:=K-1;
        if ID>=WORD[K] then I:=K+1
      until I>J;
      if I-1>J then SYM:=WSYM[K]
      else SYM:=IDENT
     end
```

FIGURE 4.9 PROCEDURE GETNEXTSYM (CONTD.)

```
else
  if (CH in ['0'..'9']) or (CH='-') then
   begin INTNUM:=0;
    REALNUM:=0.0;
    SYM:=INTNUMBER;
    if CH='-' then
     begin TEMPCH:='-';
      GETCH
     end;
    if CH in ['0'..'9'] then
     begin
      repeat INTNUM:=10*INTNUM+(ORD(CH)-ORD('0'));
        GETCH
      until not (CH in ['0'..'9']);
      if CH='.' then
       begin REALNUM:=INTNUM;
        INTNUM:=0;
        GETCH;
        SYM:=REALNUMBER;
        P:=10;
        while CH in ['0'..'9'] do
         begin REALNUM:=REALNUM+(ORD(CH)-ORD('0'))/P
          P:=P*10;
          GETCH
         end
       end
     end
    else ERROR(17);
    if TEMPCH='-' then
     begin REALNUM:=-REALNUM;
      INTNUM:=-INTNUM;
      TEMPCH:=' '
     end
   end
  else
    if CH='<' then
     begin GETCH;
      if CH='>' then
       begin SYM:=NEQ;
        GETCH
       end
      else
        if CH='=' then
         begin SYM:=LEQ;
          GETCH
         end
        else SYM:=LSS
     end
    else
      if CH='>' then
       begin GETCH;
        if CH='=' then
         begin SYM:=GEQ;
          GETCH
         end
        else SYM:=GTR
       end
      else
       begin SYM:=SSYM[CH];
        GETCH
       end
end;
```

FIGURE 4.2 PROCEDURE GETNEXTSYM

been made to indicate to the user precise error messages in case there are errors in the structure of the query. Two procedures, ERROR and WARN have been written for the purpose. A listing of these is given in Figure 4.3. In case of errors the source query is checked as far as possible for any further errors and the user is indicated of the same. The system does not produce the object query in case of syntactical errors in source query.

A procedure named CHECKQUERY is called by the main program to check the syntax of the complete source query. It also builds up a number of tables required for producing the object query at a later stage. This procedure in turn calls two procedures CONDEXP (to process the condition part) and ACT (to process the action part). CONDFAC is a procedure used by CONDEXP to check the syntax of each simple condition in the condition part. Listings of CONDEXP and ACT are given in Figures 4.4 and 4.5 respectively. Listing of CHECKQUERY is given in Figure 4.6. Now we describe the various tables the system has and builds during the process of syntax analysis.

## 4.4 Tables Maintained (Directories):

For a given data base information about the different relations and attributes of the system is kept stored in the form of tables of records. These tables are referred to very frequently during the process of running a query. We will describe these in detail.

```
procedure ERROR(N:integer);
  begin WRITELN('*',' ':CC-1,'^',N:2);
   case N of
     1: WRITELN('** Illegal Attribute name.');
     2: WRITELN('** Non negative integer expected.');
     3: WRITELN('** Comparision operator expected.');
     4: WRITELN('** Unpaired paranthesis.');
     5: WRITELN('** "<>" expected.');
     6: WRITELN('** Illegal relation name.');
     7: WRITELN('** Left paranthesis expected.');
     8: WRITELN('** Period expected.');
     9: WRITELN('** "TOP" or "BOTTOM" expected.');
    10: WRITELN('** Illegal symbol.');
    11: WRITELN('** "GET" expected.');
    12: WRITELN('** Colon expected.');
    13: WRITELN('** "UP" or "DOWN" expected.');
    14: WRITELN('** "CONDITION" expected.');
    15: WRITELN('** Illegal work space name.');
    16: WRITELN('** Illegal attribute value.');
    17: WRITELN('** Number (real or integer) expected.');
    18: WRITELN('** "=" expected.');
    19: WRITELN('** " ' " (APOSTROPHE) expected.');
    20: WRITELN('** "ACTION" expected.')
   end;
   ERR:=ERR+1
  end;

procedure WARN(N:integer);
  begin WRITELN;
   WRITELN('Warning no.',N:2);
   case N of
     1: WRITELN('-- Missing semicolon at end of query.');
     2: WRITELN('-- Totalling/Sorting not done in output relation
   end;
   WRITELN
  end;

procedure GETNAME(var ID:ALFA);
  var
   I,J,K:integer;
   CH:char;
  begin READ(F,CH);
   while CH=' ' do READ(F,CH);
   I:=1;
   while ((CH<>' ')and(I<=AL)) do
    begin ID[I]:=CH;
     I:=I+1;
     READ(F,CH)
    end;
   for J:=I to AL do ID[J]:=' '
  end;
```

FIGURE 4.3 PROCEDURES ERROR, WARN AND GETNAME

```
procedure CONDEXP;
  procedure ADDGAMA;
    begin NEW(GP2);
     GP2^.NEXTGAMA:=GP1;
     GP1:=GP2
    end;
  procedure CONDTERM;
    procedure CONDFAC;
      begin
       if SYM in [COUNTSYM,TOTALSYM,IDENT] then
       begin CN:=CN+1;
        ADDGAMA;
        GP1^.GAMAVAL:=CN;
        GP1^.GAMASYM:=INTNUMBER;
        with CONTAB[CN] do
         begin
          if SYM=COUNTSYM then
           begin CNDCD:=9;
            ATTNUC:=0;
            GETNEXTSYM;
            if SYM=LPARFN then
             begin GETNEXTSYM;
              if SYM=IDENT then
               begin GETRELNO(RELNO,ID);
                if RELNO>0 then
                 begin RELNOC:=RELNO;
                  GETNEXTSYM;
                  if SYM=SAMESYM then
                   begin NEW(P1);
                    SATTS9:=P1;
                    repeat GETNEXTSYM;
                      if SYM=IDENT then
                        begin GETATTNO(ATTNO,ID);
                         if ATTNO>0 then
                          begin P11:=P1;
                           NEW(P1);
                           P11^.NEXTATT:=P1;
                           P11^.ATTNOL:=ATTNO;
                           GETNEXTSYM
                          end
                         else ERROR(1)
                        end
                       else ERROR(1)
                    until SYM<>COMMA;
                    P11^.NEXTATT:=nil
                   end;
                  if SYM=DIFFERENTSYM then
                   begin NEW(P1);
                    DATTS9:=P1;
                    repeat GETNEXTSYM;
                      if SYM=IDENT then
                        begin GETATTNO(ATTNO,ID);
                         if ATTNO>0 then
                          begin P11:=P1;
                           NEW(P1);
                           P11^.NEXTATT:=P1;
                           P11^.ATTNOL:=ATTNO;
                           GETNEXTSYM
                          end
                         else ERROR(1)
                        end
                       else ERROR(1)
                    until SYM<>COMMA;
                    P11^.NEXTATT:=nil
                   end;
```

FIGURE 4.4 PROCEDURE CONDEXP (CONTD.)

```
            if SYM=RPAREN then
             begin GETNEXTSYM;
              if SYM in [EQL,LSS,GTR,NEQ,LEQ,GEQ] then
               begin COND:=SYM;
                GETNEXTSYM;
                if SYM=INTNUMBER then
                 begin VAL9:=INTNUM;
                  if VAL9<0 then ERROR(2);
                  GETNEXTSYM
                 end
                else ERROR(2)
               end
              else ERROR(3)
             end
            else ERROR(4)
           end
          else ERROR(6)
         end
        else ERROR(6)
       end
      else ERROR(7)
     end
    else
     if SYM=TOTALSYM then
      begin CNDCD:=8;
       ATTNOC:=0;
       GETNEXTSYM;
       if SYM=LPAREN then
        begin GETNEXTSYM;
         if SYM=IDENT then
          begin GETRELNO(RELNO,ID);
           if RELNO>0 then
            begin RELNOC:=RELNO;
             GETNEXTSYM;
             if SYM=SAMESYM then
              begin NEW(P1);
               SATTS8:=P1;
               repeat GETNEXTSYM;
                  if SYM=IDENT then
                   begin GETATTNO(ATTNO,ID);
                    if ATTNO>0 then
                     begin P11:=P1;
                      NEW(P1);
                      P11^.NEXTATT:=P1;
                      P11^.ATTNOL:=ATTNO;
                      GETNEXTSYM
                     end
                    else ERROR(1)
                   end
                  else ERROR(1)
               until SYM<>COMMA;
               P11^.NEXTATT:=nil
              end;
```

FIGURE 8.4 PROCEDURE CONDEXP (CONTD.

```
                if SYM=COLON then
                 begin GETNEXTSYM;
                  if SYM=IDENT then
                   begin GETATTNO(ATTNO,ID);
                    if ATTNO>0 then
                     begin TATT8:=ATTNO;
                      GETNEXTSYM;
                      if SYM=RPAREN then
                       begin GETNEXTSYM;
                        if SYM in [EQL,LSS,GTR,NEQ,LEQ,GEQ]
                         begin COND:=SYM;
                          GETNEXTSYM;
                          if SYM=INTNUMBER then
                           begin TOID8:=INTNUMBER;
                            VAL8I:=INTNUM;
                            GETNEXTSYM
                           end
                          else
                           if SYM=REALNUMBER then
                            begin TOID8:=REALNUMBER;
                             VAL8R:=REALNUM;
                             GETNEXTSYM
                            end
                           else ERROR(17)
                         end
                        else ERROR(3)
                       end
                      else ERROR(4)
                     end
                    else ERROR(1)
                   end
                  else ERROR(1)
                 end
                else ERROR(12)
               end
              else ERROR(6)
             end
            else ERROR(6)
           end
          else ERROR(7)
         end
        else
         if SYM=IDENT then
          begin GETRELNO(RELNO,ID);
           if RELNO>0 then
            begin RELNOC:=RELNO;
             GETNEXTSYM;
             if SYM=PERIOD then
              begin GETNEXTSYM;
               if SYM=IDENT then
                begin GETATTNO(ATTNO,ID);
                 if ATTNO>0 then
                  begin ATTNOC:=ATTNO;
                   GETNEXTSYM;
                   if SYM in [EQL,NEQ,LSS,LEQ,GTR,GEQ]
                    begin COND:=SYM;
                     GETNEXTSYM;
                     if SYM=ALLSYM then
                      begin CNOCN:=3;
                       if COND#EQL then ERROR(18);
                       GETNEXTSYM
                      end
```

FIGURE 4.4 PROCEDURE CONDEXP (CONTD.

```
else
  if SYM=STAR then
   begin CNDCD:=2;
    if COND#EQL then ERROR(18);
    GETNEXTSYM
   end
  else
    if SYM=IDENT then
     begin GETRELNO(RELNO,ID);
      if RELNO>0 then
       begin CNDCD:=7;
        RELNO7:=RELNO;
        GETNEXTSYM;
        if SYM=PERIOD then
         begin GETNEXTSYM;
          if SYM=IDENT then
           begin GETATTNO(ATTNO,ID);
            if ATTNO>0 then
             begin ATTNO7:=ATTNO;
              if COND#NEQ then ERROR(5);
              if ATTNO7#ATTNOC then
                ERROR(1);
              GETNEXTSYM
             end
            else ERROR(1)
           end
          else ERROR(1)
         end
        else ERROR(8)
       end
      else ERROR(6)
     end
    else
      if SYM=INTNUMBER then
       begin VAL4:=INTNUM;
        GETNEXTSYM;
        if SYM=TOPSYM then
         begin CNDCD:=4;
          GETNEXTSYM
         end
        else
          if SYM=BOTTOMSYM then
           begin CNDCD:=5;
            GETNEXTSYM
           end
          else ERROR(9)
       end
      else
        if SYM=APST then
         begin CNDCD:=1;
          GETNEXTSYM;
          if SYM in
          [IDENT,INTNUMBER,REALNUMBER]then
          begin TOID1:=SYM;
           case TOID1 of
             IDENT:VAL1I:=SEARCH(ATTNOC,ID);
             REALNUMBER:VALIR:=REALNUM;
             INTNUMBER:VAL1I:=INTNUM
           end;
```

FIGURE 4.4 PROCEDURE CONDEXP (CONTD.)

```
                                        GETNEXTSYM;
                                        if SYM=APST then
                                          GETNEXTSYM
                                        else ERROR(19)
                                       end
                                      else ERROR(16)
                                     end
                                    else ERROR(10)
                                 end
                               else ERROR(3)
                              end
                             else ERROR(1)
                            end
                           else ERROR(1)
                          end
                         else ERROR(8)
                        end
                       else ERROR(6)
                      end
          end
        end
      else
        if SYM=LPAREN then
         begin ADDGAMA;
          GPi^.GAMASYM:=LPAREN;
          GETNEXTSYM;
          CONDEXP;
          if SYM=RPAREN then
           begin ADDGAMA;
            GPi^.GAMASYM:=RPAREN;
            GETNEXTSYM
           end
          else ERROR(4)
         end
        else ERROR(10)
    end;
  begin CONDFAC;
   while SYM=ANDSYM do
    begin ADDGAMA;
     GPi^.GAMASYM:=ANDSYM;
     GETNEXTSYM;
     CONDFAC
    end
  end;
begin CONDTERM;
 while SYM=ORSYM do
  begin ADDGAMA;
   GPi^.GAMASYM:=ORSYM;
   GETNEXTSYM;
   CONDTERM
  end
end;
```

FIGURE 4.4 PROCEDURE CONDEXP

```
procedure ACT;
  var
   I,J,K:integer;
   FLAG:boolean;
  procedure INSERT(var I:integer);
    var
     J:integer;
     FLAG:boolean;
    begin J:=1;
     FLAG:=false;
     repeat
       if TABATT[J].ATTNOT=ATTNO then FLAG:=true;
       J:=J+1
     until (FLAG or (TABATT[J].ATTNOT=0))
     with TABATT[I] do
      begin
       if FLAG then RELNOT:=0
       else
        begin RELNOT:=RELNO;
         ATTNOT:=ATTNO;
         ACTCD:=0;
         I:=I+1
        end
      end
    end;
  begin I:=1;
   if SYM=GETSYM then
    begin GETNEXTSYM;
     if SYM=LPAREN then
      begin GETNEXTSYM;
       if SYM=COUNTSYM then
        begin ACTTAB.COUNTREQ:=true;
         GETNEXTSYM
        end
       else
         if SYM=INTNUMBER then
          begin ACTTAB.LIMNO:=INTNUM;
           ACTTAB.LITREQ:=true;
           GETNEXTSYM
          end
         else ERROR(10);
       if SYM=RPAREN then GETNEXTSYM
       else ERROR(4)
      end;
```

FIGURE 4.5 PROCEDURE ACT (CONTD...)

```
if SYM=IDENT then
 begin GETRELNO(RELNO,ID);
  if RELNO>0 then
   begin TEMPSYM:=IDENT;
    TABATT[I].RELNOT:=RELNO;
    TABATT[I].ACTCD:=1;
    GETNEXTSYM;
    if SYM=PERIOD then
     begin GETNEXTSYM;
      if SYM=IDENT then
       begin GETATTNO(ATTNO,ID);
        if ATTNO>0 then
         begin TABATT[I].ATTNOT:=ATTNO;
          J:=I+1;
          GETNEXTSYM;
          while SYM=COMMA do
           begin GETNEXTSYM;
            if SYM=IDENT then
             begin GETRELNO(RELNO,ID);
              if RELNO>0 then
               begin TABATT[I].RELNOT:=RELNO;
                GETNEXTSYM;
                if SYM=PERIOD then
                 begin GETNEXTSYM;
                  if SYM=IDENT then
                   begin GETATTNO(ATTNO,ID);
                    if ATTNO>0 then
                     begin TABATT[I].ATTNOT:=ATTNO;
                      TABATT[I].ACTCD:=1;
                      I:=I+1;
                      GETNEXTSYM
                     end
                    else ERROR(1)
                   end
                  else ERROR(1)
                 end
                else ERROR(8)
               end
              else ERROR(6)
             end
           end
         else ERROR(1)
        end
       else ERROR(1)
      end
     else ERROR(8)
    end
   else ERROR(6)
 end;
```

FIGURE 4.5 PROCEDURE ACT (CONTD.)

```
if SYM=TOTALSYM then
 begin GETNEXTSYM;
  ACTTAB.TTIREQ:=true;
  if SYM=LPAREN then
   begin GETNEXTSYM;
    if SYM=IDENT then
     begin GETRELNO(RELNO,ID);
      if RELNO>0 then
       begin ACTTAB.TREL:=RELNO;
        GETNEXTSYM;
        if SYM=SAMESYM then
         begin NEW(P1);
          ACTTAB.SATTS:=P1;
          repeat GETNEXTSYM;
            if SYM=IDENT then
             begin GETATTNO(ATTNO,ID);
              if ATTNO>0 then
               begin P11:=P1;
                INSERT(I);
                NEW(P1);
                P11^.NEXTATT:=P1;
                P11^.ATTNOL:=ATTNO;
                GETNEXTSYM
               end
              else ERROR(1)
             end
            else ERROR(1)
          until SYM#COMMA;
          P11^.NEXTATT:=nil
         end;
        if SYM=COLON then
         begin GETNEXTSYM;
          if SYM=IDENT then
           begin GETATTNO(ATTNO,ID);
            if ATTNO>0 then
             begin ACTTAB.TATT:=ATTNO;
              TABATT[I].RELNOT:=RELNO;
              TABATT[I].ATTNOT:=ATTNO;
              TABATT[I].ACTCD:=1;
              I:=I+1;
              GETNEXTSYM;
              if SYM=RPAREN then
               GETNEXTSYM
              else ERROR(4)
             end
            else ERROR(1)
           end
          else ERROR(1)
         end
        else ERROR(12)
       end
      else ERROR(6)
     end
    else ERROR(6)
   end
  else ERROR(7)
 end
```

FIGURE 4.5 PROCEDURE AUX

(CONTD.)

```
else
  if TEMPSYM<>IDENT then ERROR(10);
TEMPSYM:=NUL;
if SYM=LPAREN then
 begin ACTTAB.SRTREQ:=true;
  NEW(SP1);
  ACTTAB.PSORT:=SP1;
  repeat GETNEXTSYM;
    if SYM in [UPSYM,DOWNSYM] then
     begin
      if SYM=UPSYM then TEMPSORT:=UP
      else TEMPSORT:=DOWN;
      GETNEXTSYM;
      if SYM=IDENT then
       begin GETRELNO(RELNO,ID);
        if RELNO>0 then
         begin SP11:=SP1;
          NEW(SP1);
          SP11^.SORDER:=TEMPSORT;
          SP11^.NEXTSORT:=SP1;
          GETNEXTSYM;
          if SYM=PERIOD then
           begin GETNEXTSYM;
            if SYM=IDENT then
             begin GETATTNO(ATTNO,ID);
              if ATTNO>0 then
               begin SP11^.ATTNOS:=ATTNO;
                INSERT(I);
                GETNEXTSYM
               end
              else ERROR(1)
             end
            else ERROR(1)
           end
          else ERROR(8)
         end
        else ERROR(6)
       end
      else ERROR(6)
     end
    else ERROR(13)
  until SYM<>COMMA;
  SP1^.NEXTSORT:=nil;
  if SYM=RPAREN then GETNEXTSYM
  else ERROR(4)
 end
end
else ERROR(11)
end;
```

FIGURE 4.5 PROCEDURE ACT

```
procedure CHECKQUERY;
 procedure BLOCK;
   procedure CONDEXP;
   PROCEDURE ACT;
   begin
    if SY'=CONDITIONSym then
     begin GETNEXTSYM;
      if SY'=COLON then
       begin GETNEXTSYM;
        CN:=0;
        GPI:=nil;
        CONDEXP
       end
      else ERROR(12)
     end
    else ERROR(14);
    if SYM#ACTIONSYM then
     begin while SYM#ACTIONSYM do GETNEXTSYM;
      ERROR(20)
     end;
    GETNEXTSYM;
    if SYM=COLON then
     begin GETNEXTSYM;
      ACT
     end
    else ERROR(12)
   end;
 begin
  if SYM=IDENT then GETNEXTSYM;
  if SYM=LPAREN then
   begin GETNEXTSYM;
    if SYM=IDENT then
     begin WSPACE:=ID;
      GETNEXTSYM;
      if SYM=RPAREN then
       begin GETNEXTSYM;
        BLOCK
       end
      else ERROR(4)
     end
    else ERROR(15)
   end
  else ERROR(7)
 end;
```

FIGURE 4.6 PROCEDURE CHECKQUERY

4.4.1 Directory of Attributes in the System:

This is named ATTDIR. It is an array of dimension NOATTS, the number of attributes in the system. Each element of the array is a record of the type ATTRIBUTE. This record has two fields -

ATTNAMED : for the name of the attribute;

and TYPEATT : for the type of the field, i.e., alphanumeric (IDENT), integer (INTNUMBER) or real (REALNUMBER).

NOATTS, the number of attributes in the data base, is declared as a constant in the main program. For our example system it is set equal to 12. It has to be changed for a different data base. The specifications of the attributes are read in from a file named 'ATTDEF' by a procedure DEFINEATTS. A listing of this procedure is given in Fig. 4.7. Each line of the file ATTDEF should define one attribute. The details should be given in the following order - attribute name and the type of the attribute ('I' for integer, 'R' for real and 'A' for alphanumeric). There should be NOATTS attributes in the file. The order in which these are given is immaterial. The system stores these attributes in ATTDIR in the same order. Whenever an attribute name is encountered in the source query, a procedure GETATTNO gets the sequence number of the attribute (ATTNO) from the table ATTDIR and uses this number for storing in the runtime tables. A listing

```
procedure DEFINEATTS;
   var
    I:integer;
    TP:char;
   begin
    RESET(F,'ATTDEF');
    for I:=1 to NOATTS do
      with ATTDIR[I] do
       begin GETNAME(ID);
        ATTNAMED:=ID;
        READ(F,TP,NUCHARS);
        if TP in ['I','R','A'] then
        case TP of
          'I':TYPEATT:=INTNUMBER;
          'R':TYPEATT:=REALNUMBER;
          'A':TYPEATT:=IDENT
        end
        else
         begin WRITELN('** Error in ATTDEF -',ATTNAMED:AL);
          HALT
         end
       end
   end;

procedure GETATTNO(var N:integer;ID:ALFA);
   var
    I:integer;
   begin I:=1;
    while((I<=NOATTS-1)and(ATTDIR[I].ATTNAMED<>ID)) do I:=I+1;
    if((I<NOATTS)or((I=NOATTS)and(ATTDIR[I].ATTNAMED=ID))) then N:=I
    else N:=0
   end;

procedure READATTS;
   var
    I,J,K:integer;
    ID:ALFA;
   begin RESET(F,'TABLES');
    for I:=1 to NOATTS do
     begin
      if ATTDIR[I].TYPEATT<>INTNUMBER then
       begin GETNAME(ID);
        if ID<>ATTDIR[I].ATTNAMED then
         begin ERROR(2);
          HALT
         end
        else
         begin READ(F,J);
          for K:=1 to J do
           begin GETNAME(ID);
            TABLE[I][K]:=ID
           end
         end
       end
     end
   end;

function SEARCH(N:integer;ID:ALFA):integer;
   var
    I:integer;
    FLAG:boolean;
   begin I:=1;
    FLAG:=false;
    while not(FLAG or (I>AL)) do
     begin
      if ID=TABLE[N][I] then FLAG:=true
      else I:=I+1
     end;
    if FLAG then SEARCH:=I
    else ERROR(16)
   end;
```

FIGURE 4.7 PROCEDURES DEFINEATTS, GETATTNO, READATTS AND FUNCTION SEARCH

of procedure GETATTNO is given in Figure 4.7. A number zero is returned by the procedure in case the identifier in the source query, which is supposed to be an attribute name (as per the syntax of the language), does not match with any of the attribute names stored in the directory. An error message is printed out in the case.

For each attribute which is not of the type integer, we read in a table which associates a unique integer number with each different type of value for that attribute. These tables are read in from a file 'TABLES' by a procedure READATTS. A listing of this procedure is given in Fig.4.7. The file 'TABLES' should contain the name of the attribute, the number of different values of the attribute and the actual values of the attributes for each of the attributes which is not of the type integer.

4.4.2 Directory of Relations Stored in the System:

This is named RELDIR. It is an array of dimension NORELSP. NORELS is the number of relations originally stored in the system.

NORELSP = NORELS + 20.

This number is chosen such that we can store all the intermediate relations built by the user. Each element of the array RELDIR is a record of the type RELATION. This record has six fields -

RELNAMED : for the name of the relation;

ATTD : for the attributes in the relation. This is an array of integers (one integer for each attribute) of dimension NOATTS (to take care of the extreme case when there is a relation in the system which contains all the attributes in the system). These integers are the same as the sequence numbers of the attributes in ATTDIR. Order is maintained and a 'ZERO' means no more attributes beyond that index;

KEYD : for the key fields of the relation. This is also an array of the same type as ATTD;

FRSTPL : is a pointer to the first tuple in the relation. (Each tuple is a record of NOATTS fields. In addition it has a MARKing facility, used at the time of implementing the algebraic operations, and a pointer to the next tuple in the relation.);

NTPLS : for storing the number of tuples in the relation;

and RELFL : for storing the name of the file in which the relation is stored.

NORELS, the number of relations defined in the data base and NORELSP, the total number of relations permitted in the

system are also declared as constants in the main program. For our example system they are set equal to 4 and 24 respectively. Th se have to be changed for a different data base. The specifications of the relations are read in from a file 'RELDEF' by a procedure DEFINERELS. A listing of this procedure is given in Fig. 4.8. Each relation should be defined in this file. The details should be given in the following order - relation name, the number of attributes in the relation, the names of the attributes in the relation, the number of fields which together form the key to the tuples in the relation, the attribute names which form the key, the number of tuples stored in the relation and finally the name of the file which contains the relation. There should be definitions of NORELS relations in this file. As in the case of ATTDIR, the order of relations in this file is immaterial. The system stores these relations in the same order in RELDIR. Whenever a relation name is encountered in the source query, a procedure GETRELNO gets the sequence number of the relation (RELNO) from RELDIR and uses this number for storing in the runtime tables. A listing of procedure GETRELNO is given in Fig. 4.8. An illegal relation name in the source query causes an error message to be printed out for the user.

Each of the relations in the system is stored in a file each. The names of these files is read from the file 'RELDEF' and stored in directory RELDIR as described above. The relations

```
procedure DEFINERELS;
  var
    I,J,K:integer;
    ID:ALFA;
  begin RESET(F,'RELDEF');
   for I:=1 to NORELS do
     with RELDIR[I] do
      begin  GETNAME(ID);
       RELNAMED:=ID;
       READ(F,J);
       for K:=1 to J do
        begin GETNAMED(ID);
         GETATTNO(ATTNO,ID);
         if ATTNO=0 then
          begin WRITELN('** Error in RELDEF =',RELNAMED:AL);
           HALT
          end;
         ATTD[K]:=ATTNO
        end;
       for K:=J+1 to NOATTS do ATTD[K]:=0;
       READ(F,J);
       for K:=1 to J do
        begin GETNAMED(ID);
         GETATTNO(ATTNO,ID);
         if ATTNO=0 then
          begin WRITELN('** Error in RELDEF =',RELNAMED:AL);
           HALT
          end;
         KEYD[K]:=ATTNO
        end;
       for K:=J+1 to NOATTS do KEYD[K]:=0;
       READ(F,NTPLS);
       GETNAME(ID);
       RELFL:=ID
      end
  end;

procedure GETRELNO(var N:integer;ID:ALFA);
  var
    I:integer;
  begin I:=1;
   while((I<=NORELSP-1)and(RELDIR[I].RELNAMED<>ID)) do I:=I+1;
   if ((I<NORELSP)or((I=NORELSP)and(RELDIR[I].RELNAMED=ID))) then N:=I
   else N:=0
  end;

procedure READRELS;
  var
    I,J,K:integer;
    TPL1,TPL2:^TUPLE;
  begin for I:=1 to NORELS do
      with RELDIR[I] do
       begin RESET(F,RELFL);
        NEW(TPL1);
        FRSTPL:=TPL1;
        for K:=1 to NTPLS do
         begin J:=1;
          while ATTD[J]<>0 do
           begin
            if ATTDIR[ATTD[J]].TYPEART=INTNUMBER then
              READ(F,TPL1^.FIELD[J])
            else
             begin GETNAME(ID);
              TPL1^.FIELD[J]:=SEARCH(ATTD[J],ID);
             end;
            J:=J+1
           end;
          TPL2:=TPL1;
          NEW(TPL1);
          TPL2^.NXTPL:=TPL1
         end;
        TPL2^.NXTPL:=nil
       end
  end;
```

FIGURE 4.8 PROCEDURES DEFINERELS,GETRELNO

ADD READRELS

are read by procedure READREL, a listing of which is given in Fig. 4.8. Each file contains the values of the attributes in the same order in which the attribute names were defined in 'RELDEF'. The integer values are read and stored in the tuples as such. The non-integer values are read and their corresponding number is obtained from the tables, which have been read from the file 'TABLES'. These numbers are stored in the tuples. A procedure SEARCH, a listing of which is given in Fig. 4.7, does the job of getting the number for each non-integer value read.

4.4.3 Common Attribute and Common Relation Tables:

These are the most important tables in the system and are used at the time of producing the object query. The basic assumption in our system is made use of in these tables. To state explicitly, the assumption is that two different relations in the system are either related through a common attribute, or, if there is no common attribute between the two, there is atmost one other relation (in the user's sub-schema) which relates these two relations. In other words, for two relations R1 and R2, either there is one and only one attribute A1 which is common to both R1 and R2 (this is true in case the relations are in 3NF), or there exists atmost one other relation R3 such that there is an attribute A1 common to both R1 and R3 and there is another attribute A2 common to both R2 and R3.

In case there is no such A1 (common to R1 and R2) and there is no such R3 (common to R1 and R2) and the source query involves two such relations, then the object query is not produced and the user is asked to break up his query into simpler subqueries so that the above assumption becomes true. This breaking up is always possible if the query is meaningful. It has to be pointed out here that in most of the queries, commonly made by a genuine user, such a condition will not arise. The provision of giving this message to the user is required so that he may know that either his subschema is not complete or that his query is extremely complicated.

Based on this assumption, we build up two tables -COMATT and COMREL to store all such information. Both these tables are two dimensional arrays of size NORELSP X NORELSP. The enteries in these tables are made according to the following rules -

COMATT [i,j] = 0 if i and j are two relations that have no attribute in common.

COMATT [i,j] = k if k is an attribute that is common to relations i and j.

COMREL [i,j] = 0 if there is no relation in common to relations i and j, or COMATT [i,j] $\neq$ 0.

COMREL [i,j] = k if relation k is common to relations i and j, and COMATT [i,j] = 0.

Here i,j and k are the sequence numbers of the attributes and relations in ATTDIR and RELDIR respectively. These tables are initialized (for the relations read in) by the procedure BLDCOMTABS. A listing of this procedure is given in Fig.4.9.

In case of a multi-step query, after the processing of each sub-query, these tables are updated to include the final relation built by the user in that sub-query. This is done because the next sub-query is very likely to involve the relation built by the previous sub-query. A procedure MDFCOMTAB has been written for the purpose. A listing of this procedure is given in Fig. 4.10.

## 4.5 Tables Built (Run Time):

During the processing of any query, information contained in the source query about the type of the condition part and the attributes and relations involved therein, and the action required and the attributes and relations involved therein has to be stored in some form to enable the object query generator to perform its task. Now we describe these tables in details.

### 4.5.1 Table for Condition Part:

This has been given the name CONTAB. It is an array (of size 10) of records for the general case of a complex condition. This record has four fields common for all types (refer to the 7 condition types described in Chapter III) of conditions and different number of more fields each depending on the type of the condition.

```
procedure BLOCOMTABS;
  begin
    for I:=1 to NORELSP do
      for J:=1 to NORELSP do
        begin COMATT[I,J]:=0;
          COMREL[I,J]:=0
        end;
    for I:=1 to NORELS do
      for J:=1 to NORELS do
        if I<>J then
          begin FLAG:=false;
            K:=1;
            repeat L:=RELDIR[I].ATTD[K];
              M:=1;
              repeat
                if L=RELDIR[J].ATTD[M] then FLAG:=true;
                M:=M+1
              until (FLAG or(RELDIR[J].ATTD[M]=0));
              K:=K+1
            until (FLAG or(RELDIR[I].ATTD[K]=0));
            if FLAG then COMATT[I,J]:=L
          end;
    for I:=1 to NORELS do
      for J:=1 to NORELS do
        if ((I<>J)and(COMATT[I,J]<>0)) then
          begin K:=1;
            FLAG:=false;
            repeat
              if ((COMATT[I,K]<>0)and(COMATT[J,K]<>0)) then FLAG:=true
              else K:=K+1
            until(FLAG or (K>NORELS));
            if FLAG then COMREL[I,J]:=K
          end
  end;

procedure CLEARTABLES;
  var
    I:integer;
  begin I:=1;
    while TABATT[I].RELNOT<>0 do
      begin TABATT[I].RELNOT:=0;
        TABATT[I].ATTNOT:=0;
        TABATT[I].ACTCD:=0;
        I:=I+1
      end;
    with ACTTAB do
      begin SRTREQ:=false;
        TTLREQ:=false;
        COUNTREQ:=false;
        CNTREQ:=false
      end
  end;
```

FIGURE 4.9 PROCEDURES BLOCOMTABS AND CLEARTABLES

```
procedure  DEC[illegible]AB;
  var
   I,J,K,L:integer;
   FLAG:boolean;
  begin
   for I:=1 to NORELS do
    begin J:=1;
     FLAG:=false;
     repeat
       if TABATT[J].RELNOT=I then FLAG:=true
       else J:=J+1
     until (FLAG or (TABATT[J].ACTCD=0));
     if FLAG then
      begin L:=J;
       FLAG:=false;
       repeat K:=1;
         repeat
           if TABATT[L].ATTNOT=RELDIR[I].KEYD[K] then FLAG:=true
           else K:=K+1
         until (FLAG or (RELDIR[I].KEYD[K]=0));
         if not FLAG then L:=L+1
       until (FLAG or (TABATT[L].ACTCD=0));
       if FLAG then
        begin COMATT[I,IREL]:=TABATT[L].ATTNOT;
         COMATT[IREL,I]:=TABATT[L].ATTNOT
        end
       else
        begin COMATT[I,IREL]:=TABATT[J].ATTNOT;
         COMATT[IREL,I]:=TABATT[J].ATTNOT
        end
      end
    end;
   J:=1;
   repeat K:=TABATT[J].ATTNOT;
     for I:=1 to NORELS do
      begin
       if COMATT[I,IREL]=0 then
        begin L:=1;
         FLAG:=false;
         repeat
           if RELDIR[I].ATTD[L]=K then FLAG:=true
           else L:=L+1
         until (FLAG or (RELDIR[I].ATTD[L]=0));
         if FLAG then
          begin COMATT[I,IREL]:=K;
           COMATT[IREL,I]:=K
          end
        end
      end;
     J:=J+1
   until TABATT[J].ACTCD=0;
   for I:=1 to NORELS do
    begin
     if COMATT[I,IREL]=0 then
      begin J:=1;
       FLAG:=false;
       repeat
         if ((COMATT[I,J]=0) or (COMATT[IREL,J]=0)) then J:=J+1
         else
          begin COMREL[I,IREL]:=J;
           FLAG:=true;
           COMREL[IREL,I]:=J
          end
       until ((J>NORELS) or FLAG)
      end
    end
  end;
```

FIGURE 4.10 PROCEDURE MOFCONTAB

First let us define a variable CNDCD for the condition codes. It is of the type CONDCODE which can take integer values from 1 to 9. Each of these values (except 6 which is not used presently - it can be used for adding any future types of conditions) corresponds to one of the condition types. The four common fields in record CONTAB are -

RELNOC : for storing the relation number of the relation on the left hand side of the comparison operator in the condition;

ATTNOC : for storing the attribute number of the attribute on the left hand side of the comparison operator in the condition. It stores the value 'zero' in case CNDCD = 8 or 9. (For CNDCD refer next page);

COND : for storing the comparison operator involved in the condition;

and CNDCD : this stores the type of the condition.

The variable fields for different values of CNDCD are as follows-

CNDCD = 1 (relation.attribute <COND> " value ")

VAL1A or VAL1I or VAL1R : to store the value within the quotes, depending upon whether it is alphanumeric or integer or real respectively.

CNDCD = 2 (relation.attribute = *)

No special fields.

First let us define a variable CNDCD for the condition codes. It is of the type CONDCODE which can take integer values from 1 to 9. Each of these values (except 6 which is not used presently - it can be used for adding any future types of conditions) corresponds to one of the condition types. The four common fields in record CONTAB are -

RELNOC : for storing the relation number of the relation on the left hand side of the comparison operator in the condition;

ATTNOC : for storing the attribute number of the attribute on the left hand side of the comparison operator in the condition. It stores the value 'zero' in case CNDCD = 8 or 9. (For CNDCD refer next page);

COND : for storing the comparison operator involved in the condition;

and CNDCD : this stores the type of the condition.

The variable fields for different values of CNDCD are as follows-

CNDCD = 1 (relation.attribute <COND> " value")

VAL1A or VAL1I or VAL1R : to store the value within the quotes, depending upon whether it is alphanumeric or integer or real respectively.

CNDCD = 2 (relation.attribute = *)

No special fields.

CNDCD = 3 (relation.attribute = ALL)

No special fields.

CNDCD = 4 (relation.attribute <COND> n TOP)

VAL4 : for storing the value of 'n'.

CNDCD = 5 (relation.attribute <COND> n BOTTOM)

VAL4 : for storing the value of 'n'.

CNDCD = 6 (not used presently)

CNDCD = 7 (relation.attribute <> relation.attribute)

RELNO7 : for storing the relation number of the relation on the right hand side of the comparison operator.

ATTNO7 : for storing the attribute number of the attribute on the right hand side of the comparison operator.

CNDCD = 8 (TOTAL(relation SAME attributes:attribute) <COND> value

SATTS8 : pointer to a list of nodes of the type ATTNOD. This list contains the attribute numbers of attributes in the SAME list.

TATT8 : for storing the attribute number of the attribute of which the total has to be checked.

VAL8I or VAL8R : to store the value on the right hand side of the comparison operator, depending upon whether it is integer or real respectively.

CNDCD = 9 (COUNT(relation SAME attributes DIFFERENT attributes) <COND> positive integer)

SATTS9 : pointer to a list of nodes of type ATTNODE. This list contains the attribute numbers of attributes in the SAME list.

DATTS9 : pointer to the list of attributes in the DIFFERENT list.

VAL9 : stores the non-negative integer value on the right hand side of the comparison operator.

4.5.2 Tables for Action Part:

Two tables are built for the purpose of storing information in the action part of the source query. One is used for storing the numbers of attributes and relations that are required to perform the task asked for in the action part. Other is for storing the final action required on the relation to be outputted to the user's work space. We discuss these tables in greater detail now.

Table of Attributes Required:

This is named as TABATT. It is an array of size NOATTS. Each element is a record of type ATTSUSED. It has 3 fields -

ATTNOT : for storing the attribute number of the attribute in the list of attributes in the action part;

RELNOT : for storing the relation number of the relation in whose context that attribute has been used;

and ACTCD : (ACTion CoDe) for storing the reason for which that attribute is used in the action part. This stores the value 'zero' if the attribute is not

to be outputted in the final relation (and has to be brought temporarily for the purpose of sorting and/or totalling). If it is an output attribute then this field stores the value 'one'.

In case sorting and/or totalling is required before finally outputting the relation, the field ACTCD is made use of to remove those attributes from the final relation which have 'zero' in this field.

Table for Actions Required:

This is named as ACTTAB. It is a record of the type ACTION which has the following fields -

SRTREQ : a boolean variable which stores 'true' if sorting is required before outputting;

PSORT : a pointer to the list of SORTNODES. This node contains the attribute number (ATTNOS) and sort order (SORDER) of that attribute. The first attribute in the list is the major field and rest, if any, are subsequent minor fields for sorting. SORDER stores 'UP' or 'DOWN' as the case may be;

TTLREQ : a boolean variable which stores 'true' if totalling of a certain domain is required;

TREL : for storing the relation number of the relation involved in doing the totalling;

SATTS : a pointer to the list of attribute numbers of attributes in the SAME list;

TATT : for storing the number of the attribute of which the totalling has to be done;

COUNTREQ : a boolean variable which stores 'true' if count of the number of tuples in the final relation is required;

LMTREQ : a boolean variable which stores 'true' if the number of tuples to be outputted is to be limited to a certain number;

LIMNO : for storing the number of tuples to be outputted if LMTREQ is true.

These two tables, ACTTAB and TABATT are cleared before the processing of any query (or sub-query in case of a multi-step query). This is done by the procedure CLEARTABLES, a listing of which is given in Fig. 4.9.

## 4.6 Object Query Generation.

The runtime tables, that have been just described, and the system's maintained tables, that were described earlier in this chapter, are together used to convert the intent of the source query to statements in the object query. These statements are the usual relational algebra operations like project, join, divide etc.

A different sequence of steps is required for each of the different condition codes (CNDCD) stored in the condition

table (CONTAB). The numbers of the relations involved are stored in CONTAB and TABATT. We denote the relation and the attribute on the left hand side of the comparison operator in the condition part as RC and AC respectively. One idea has to be brought out which is common to all condition codes. It is that TABATT contains the numbers of all relations (along with the attributes) that are to be brought to the work space. Four different cases are possible :

(i) All the relations in TABATT are same as RC.

(ii) There exist relations in TABATT which are different from RC but have an attribute each common to it. (This can be checked from the COMATT table described earlier).

(iii) There exist relations in TABATT which are different from RC, have no common attribute with it, but have a relation each common to it. (This can be checked from the table COMREL described earlier), or

(iv) None of the above three, i.e., the relations, different from RC, in TABATT do not have even a relation in common with RC.

We will describe, after a while, the sequence of actions for each of the condition codes for case (i) only. However, the system takes care of all cases in the following way -

A procedure CHECK (FLAG,I) checks the relations in TABAT to see if they are different from RC. If it finds no such relation then the value of FLAG is set to 'false' (case (i)).

Else FLAG is set to 'true' and then 'I' points to that entry in TABATT which has such a relation. A procedure BUILD is invoked if FLAG is found to be true. This procedure joins to RC all the relations in TABATT which are different from RC. It scans TABATT completely and for each of the relations found to be different from RC (and any of the previous relations encountered in TABATT so far) it checks up tables COMATT and COMREL. Let R1 be such a relation. If COMATT [R1,RC] is not zero (case (ii)), then it joins to RC (or the relation built up so far as a result of previous such relations encountered in TABATT) this relation R1. If it is zero then it goes on to checking COMREL [R1,RC]. If this is not zero then (case (iii)) R1 and the relation from COMREL are joined to RC (or the relation built so far). If this is also zero (case (iv)) then no actions are taken as it means that the query is either very complicated or it is meaningless. A procedure DUMP is then called which asks the user to split the query into simpler sub-queries and run again as a multi-step query. This is always possible to be done if the query is meaningful. A listing of procedures CHECK,BUILD and DUMP is given in Fig. 4.11.

Now we go on to describing the sequence of relational algebra operations to be performed for each of the 8 types of condition codes for case (i) only.

```
procedure CHECK(var FLAG:boolean; var I:integer);
 var
  K:integer;
 begin I:=I+1;
  FLAG:=false;
  repeat
    if((TABATT[I].RELNOT#0)and(TABATT[I].RELNOT#RC))then
     begin FLAG:=true;
      if I>1 then
       begin K:=1;
        repeat
          if TABATT[I].RELNOT=TABATT[K].RELNOT then FLAG:=false;
          K:=K+1
        until K>=I
       end
     end;
    if not FLAG then I:=I+1
  until (FLAG or (TABATT[I].RELNOT=0))
 end;

procedure BUILD;
 procedure DUMP;
   var
    I:integer;
   begin for I:=1 to 4 do WRITELN;
    WRITE('*****ERROR : Split the Query into smaller Queries ');
    WRITELN('and run again.');
    HALT
   end;
 begin R1:=TABATT[1].RELNOT;
  A1:=COMATT[R1,RC];
  if A1#0 then JOIN(R1,A1,RC)
  else
   begin R2:=COMREL[R1,RC];
    if R2#0 then
     begin A1:=COMATT[R1,R2];
      JOIN(R1,A1,R2);
      A2:=COMATT[R2,RC];
      JOIN(RC,A2,IREL)
     end
    else DUMP
   end;
  CHECK(FLAG,I);
  while FLAG do
   begin R1:=TABATT[I].RELNOT;
    A1:=COMATT[R1,RC];
    if A1#0 then JOIN(R1,A1,IREL)
    else
     begin R2:=COMREL[R1,RC];
      if R2#0 then
       begin A1:=COMATT[R1,R2];
        JOIN(R1,A1,R2);
        A2:=COMATT[RC,R2];
        JOIN(IREL-1,A2,IREL)
       end
      else DUMP
     end;
    CHECK(FLAG,I)
   end
 end;
```

FIGURE 4.11 PROCEDURES CHECK, BUILD AND DUMP

CNDCD = 1 (RC.AC <COND> 'value')

In this case RC is projected on the required attribute bringing only those tuples for which 'AC <COND> value' is satisfied.

i.e., PROJECT RC BY attributes in TABATT WHERE AC <COND> value;

CNDCD = 2 (RC.AC = *)

This is converted to just the following -

PROJECT RC BY attributes in TABATT;

CNDCD = 3 (RC.AC = ALL)

This is converted to the following three steps -

PROJECT RC BY attributes in TABATT and AC;

PROJECT RC BY AC;

DIVIDE first relation BY second relation;

CNDCD = 4 (RC.AC <COND> n TOP)

This is converted to the following steps -

FIND n-th value of AC from top; and then like CNDCD = 1,

PROJECT RC BY attributes in TABATT WHERE AC <COND> value;

CNDCD = 5 (RC.AC <COND> n BOTTOM)

Here the steps are same as in CNDCD = 4 except that the n-th value from bottom is found.

CNDCD = 7 (RC.AC <> R7.A7)

Here AC is same as A7. This is converted to -

PROJECT RC BY AC; (giving relation 1)

PROJECT R7 BY A7; (giving relation 2)

SUBTRACT relation 2 FROM relation 1; (giving relation 3)
JOIN RC AND relation 3; and finally,
PROJECT above relation BY attributes in TABATT;

CNDCD=8 (TOTAL (RC SAME attributes A8) <COND> value)

This is converted to only one step but the projection involved is more complicated than ordinary projection. The step is -

PROJECT RC BY attributes in TABATT WHERE (total of A8 for the same attributes) <COND> value;

CNDCD=9 (COUNT (RC SAME attributes DIFFERENT attributes) <COND> integer

Here also the projection operation is slightly complicated. The step is -

PROJECT RC BY attributes in TABATT WHERE (number of tuples with the same attributes and the different attributes <COND> integer;

A procedure RUNPARTQUERY checks the CNDCD for each simple condition in the condition part and produces suitable steps of the object query as explained above. A listing of this procedure is given in Fig. 4.14.

The procedure COND EXP which checks the syntax of the complete condition part (which could be an arbitrary expression of simple conditions) builds up a list structure to store the 'infix form' of that part. This list is pointed at by pointer GP

A procedure is written to convert this infix notation to 'pre-fix notation'. This procedure is named CNVTIFTOPF and a listing of the same is given in Fig. 4.12. This prefix form is then used to produce object query statements (operations UNION and INTERSECTION) by a procedure CMBNFEL, a listing of which is given in Fig. 4.13. This procedure combines all the final relations (of each simple condition ) to produce a relation which can be outputted after actions, as stored in the table ACTTAB, have been performed on it.

The four possible actions required to be taken on the final relation are stored in the table ACTTAB and are -

(i) finding the total number of tuples in the final relation;
(ii) doing the total of certain domain in the final relation;
(iii) sorting the final relation on some domain; and
(iv) limiting the number of tuples to be retained in the final relation.

A flag for each of these is kept in ACTTAB. We note that if the count of the number of tuples is required then none of the other three operations are required to be performed. Otherwisex any combination of the other three operations could have been asked for. The sequence is - totalling, sorting and then limiting.

A listing of procedure RUNQUERY, which performs all these actions, is given in Fig. 4.15 for further details. Finally procedure OUTREL, a listing of which is also given in Fig. 4.15, outputs the final relation with proper formating.

```
edure CHKTIFTOPP;
ar
SYM:SYMBOL;
egin GP3:=nil;
GP2:=nil;
hile GP1<>nil do
 begin SYM:=GP1^.GAMASYM;
  if SYM=INTNUMBER then
   begin GP4:=GP1;
    GP1:=GP1^.NEXTGAMA;
    GP4^.NEXTGAMA:=GP3;
    GP3:=GP4
   end
  else
    if SYM=LPAREN then
     begin while GP2^.GAMASYM<>RPAREN do
       begin GP4:=GP2;
        GP2:=GP2^.NEXTGAMA;
        GP4^.NEXTGAMA:=GP3;
        GP3:=GP4
       end;
      GP2:=GP2^.NEXTGAMA;
      GP1:=GP1^.NEXTGAMA
     end
    else
      if SYM=RPAREN then
       begin GP4:=GP1;
        GP1:=GP1^.NEXTGAMA;
        GP4^.NEXTGAMA:=GP2;
        GP2:=GP4
       end
      else
        if SYM=ORSYM then
         begin GP4:=GP1;
          GP1:=GP1^.NEXTGAMA;
          GP4^.NEXTGAMA:=GP2;
          GP2:=GP4
         end
        else
          if SYM=ANDSYM then
           begin FLAG:=false;
            repeat
              if GP2=nil then FLAG:=true
              else
                if GP2^.GAMASYM<>ORSYM then FLAG:=true
                else
                 begin GP4:=GP2;
                  GP2:=GP2^.NEXTGAMA;
                  GP4^.NEXTGAMA:=GP3;
                  GP3:=GP2
                 end
            until FLAG;
            GP4:=GP1;
            GP1:=GP1^.NEXTGAMA;
            GP4^.NEXTGAMA:=GP2;
            GP2:=GP4
           end
 end;
while GP2<>nil do
 begin GP4:=GP2;
  GP2:=GP2^.NEXTGAMA;
  GP4^.NEXTGAMA:=GP3;
  GP3:=GP4
 end;
while GP3<>nil do
 begin GP4:=GP3;
  GP3:=GP3^.NEXTGAMA;
  GP4^.NEXTGAMA:=GP1;
  GP1:=GP4
 end
nd;
```

FIGURE 4.13 PROCEDURE CHKTIFTOPP

```
procedure COMBNRELS;
   procedure UNION(R1,R2:integer);
   procedure INTERSECT(R1,R2:integer);
   begin GP2:=GP1;
    GP3:=GP2^.NEXTGAMA;
    while GP3<>nil do
     begin GP4:=GP3^.NEXTGAMA;
      while GP4^.GAMASYM=INTNUMBER do
       begin GP2:=GP3;
        GP3:=GP4;
        GP4:=GP4^.NEXTGAMA
       end;
      R1:=GP2^.GAMAVAL;
      R2:=GP3^.GAMAVAL;
      if GP4^.GAMASYM=ORSYM then UNION(R1,R2)
      else INTERSECT(R1,R2);
      GP2^.GAMAVAL:=IREL;
      GP2^.NEXTGAMA:=GP4^.NEXTGAMA;
      GP2:=GP1;
      GP3:=GP2^.NEXTGAMA
     end
   end;

 procedure GIVENAME;
   begin
    case (IREL-NORELS) of
      1: RELDIR[IREL].RELNAMED:='WTEMP1     ';
      2: RELDIR[IREL].RELNAMED:='WTEMP2     ';
      3: RELDIR[IREL].RELNAMED:='WTEMP3     ';
      4: RELDIR[IREL].RELNAMED:='WTEMP4     ';
      5: RELDIR[IREL].RELNAMED:='WTEMP5     ';
      6: RELDIR[IREL].RELNAMED:='WTEMP6     ';
      7: RELDIR[IREL].RELNAMED:='WTEMP7     ';
      8: RELDIR[IREL].RELNAMED:='WTEMP8     ';
      9: RELDIR[IREL].RELNAMED:='WTEMP9     ';
     10: RELDIR[IREL].RELNAMED:='WTEMP10    ';
     11: RELDIR[IREL].RELNAMED:='WTEMP11    ';
     12: RELDIR[IREL].RELNAMED:='WTEMP12    ';
     13: RELDIR[IREL].RELNAMED:='WTEMP13    ';
     14: RELDIR[IREL].RELNAMED:='WTEMP14    ';
     15: RELDIR[IREL].RELNAMED:='WTEMP15    ';
     16: RELDIR[IREL].RELNAMED:='WTEMP16    ';
     17: RELDIR[IREL].RELNAMED:='WTEMP17    ';
     18: RELDIR[IREL].RELNAMED:='WTEMP18    ';
     19: RELDIR[IREL].RELNAMED:='WTEMP19    ';
     20: RELDIR[IREL].RELNAMED:='WTEMP20    ';
    end
   end;
```

FIGURE 4.13 PROCEDURES COMBNRELS AND GIVENAME

```
procedure RUNPARTQUERY(CN:integer);
  var
   P1,P2,R3,RC:integer;
   A1,A2,AC:integer;
   I,J,L:integer;
   FLAG:boolean;
   PA[P1,PATR2:PTR1;
   JP:array[1..NOATTS] of integer;
  procedure FINDNTH(R,A,N:integer;FLAG:boolean);
  procedure CHECK(var FLAG:boolean; var l:integer);
  procedure PROJECT(R:integer;PATR:PTR1);
  procedure JOIN(R1,A,P2:integer);
  procedure BUILD;
  procedure DIVIDE(R1,R2:integer);
  procedure SUBTRACT(R1,R2:integer);
  begin MKTFLM;
   with CONTAB[CN] do
    begin J:=1;
     NEW(P1);
     PATR1:=P1;
     repeat P11:=P1;
       NEW(P1);
       P11^.ATTNOL:=TABATT[J].ATTNOT;
       P11^.NEXTATT:=P1;
       J:=J+1
     until TABATT[J].ATTNOT=0;
     if CNDCD=3 then
      begin P1^.NEXTATT:=nil;
       P1^.ATTNOL:=ATTNOC
      end
     else P11^.NEXTATT:=nil;
     RC:=RELNOC;
     AC:=ATTNOC;
     case CNDCD of
       1,2,4,5,8,9:
          begin
           if ((CNDCD=4) or (CNDCD=5)) then
            begin
             if CNDCD=4 then FLAG:=true
             else FLAG:=false;
             TOID1:=ATTDIR[AC].TYPEATT;
             CNDCD:=1;
             FINDNTH(RC,AC,VAL4,FLAG)
            end;
           I:=0;
           CHECK(FLAG,I);
           if not FLAG then PROJECT(RC,PATR1)
           else
            begin BUILD;
             PROJECT(IREL,PATR1)
            end;
           with ACTTAB do
           if not(TILREQ or COUNTREQ) then RMVDPLCT(IREL)
          end;
```

FIGURE 4.14 PROCEDURE RUNPARTQUERY (CONTD.)

```
      3:
          begin NEW(P1);
           PATR2:=P1;
           P1^.NEXTATT:=nil;
           P1^.ATTNO:=AC;
           I:=0;
           CHECK(FLAG,I);
           if not FLAG then
            begin PROJECT(RC,PATR1);
             RMVDPLCT(IREL);
             PROJECT(RC,PATR2);
             RMVDPLCT(IREL);
             DIVIDE(IREL-1,IREL)
            end
           else
            begin BUILD;
             PROJECT(IREL,PATR1);
             RMVDPLCT(IREL);
             PROJECT(RC,PATR2);
             RMVDPLCT(IREL);
             DIVIDE(IREL-1,IREL)
            end
          end;
      7:
          begin R1:=RELNO7;
           NEW(P1);
           PATR2:=P1;
           P1^.NEXTATT:=nil;
           P1^.ATTNO:=AC;
           PROJECT(RC,PATR2);
           RMVDPLCT(IREL);
           PROJECT(R1,PATR2);
           RMVDPLCT(IREL);
           SUBTRACT(IREL-1,IREL);
           J:=IREL;
           I:=0;
           CHECK(FLAG,I);
           if not FLAG then
            begin JOIN(RC,AC,J);
             PROJECT(IREL,PATR1)
            end
           else
            begin BUILD;
             JOIN(IREL,AC,J);
             PROJECT(IREL,PATR1)
            end;
           with ACTTAB do
           if not (TTLREQ or COUNTREQ) then RMVDPLCT(IREL)
          end
    end
  end
end;
```

FIGURE 4.14 PROCEDURE RUNBARSQUERY

```
procedure RUNQUERY;
  procedure GIVENAME;
  procedure RUNSELCT(R:integer);
  procedure RUNPARTQUERY(CN:integer);
  procedure CNVTIFTOPF;
  procedure CHANRELS;
  procedure FINDCOUNT(R:integer);
  procedure DOTOTAL(R:integer);
  procedure SORTOUT(R:integer);
  procedure LIMITED(R:integer);
  begin
   repeat RUNPARTQUERY(CN);
     GP2:=GP1;
     while GP2^.GAMAVAL#CN do GP2:=GP2^.NEXTGAMA;
     GP2^.GAMAVAL:=IREL;
     CN:=CN-1
   until CN=0;
   CNVTIFTOPF;
   CHANRELS;
   with ACTTAB do
    begin
     if COUNTREQ then
      begin
       if(TTLREQ or LMTREQ or SRTREQ) then WARN(2);
       FINDCOUNT(IREL)
      end
     else
      begin
       if TTLREQ then DOTOTAL(IREL);
       if SRTREQ then SORTOUT(IREL);
       if LMTREQ then LIMITED(IREL)
      end
    end;
   if ERR=0 then
    begin WRITELN(WSPACE:AL,' = ',RELDIR[IREL].RELNAMED:AL);
     RELDIR[IREL].RELNAMED:=WSPACE
    end
  end;

procedure OUTREL(R:integer);
  var
   I:integer;
  procedure DISPLAYREL(R:integer);
  begin
   if ACTTAB.COUNTREQ then
    begin for I:=1 to 60 do WRITE('*');
     for I:=1 to 4 do WRITELN;
     WRITELN('Number of tuples in output relation is ',KOUNT)
    end
   else DISPLAYREL(R);
   for I:=1 to 3 do WRITELN;
   for I:=1 to 60 do WRITE('*');
   WRITELN
  end;
```

FIGURE 4.15 PROCEDURES RUNQUERY AND OUTREL

One more thing to be pointed here is that we have built a number of intermediate relations during the process of executing a query. Each of these relations is to be stored as soon as it is built so that the further operations can make use of them. 'IREL' is a global variable which always points to the latest relation built by the system. Each relation is also given a name by the system. This is done by a procedure GIVENAME, a listing of which is given in Fig. 4.13.

In case of a multi-step query, the final relation of each sub-query is given the name specified as the workspace area for that subquery. The entire procedure described so far is repeated for each of the sub-queries that follow. Only difference is that the COMATT and the COMREL tables are modified and all runtime action tables are cleared before starting with each of the subsequent subquery. The last sub-query ends with a semicolon and then the final relation, named by the final sub-query, is outputted after proper formating. A listing of the main program is given in Fig.4.16.

## 4.7 Summary

In this chapter we have shown how the system converts the source query (in the newly specified language) to relational algebra operations (which we have called the object query). We have described in details the tables and procedures required for the purpose. Listed in Fig. 4.17 are the outputs

```
onst
 NOKW=14;
 NORELSP=24;
 NOATTS=12;
 NORELS=4;
 AL=10;
ype
 SYMBOL=(IDENT,INTNUMBER,REALNUMBER,LPAREN,RPAREN,COLON,
         PERIOD,COMMA,SEMICOLON,EOL,LSS,GTR,NEQ,LEQ,GEQ,
         APOST,STAR,ACTIONSYM,ALLSYM,BOTTOMSYM,NUL,ORSYM,
         CONDITIONSym,COUNTSYM,SAMESYM,GETSYM,ANDSYM,
         DIFFERENTSym,TOPSYM,TOTALSYM,UPSYM,DOWNSYM);
 ALFA=packed array[1,.AL] of char;
 UPDOWN=(UP,DOWN);
 PTR1=^ATTNODE;
 ATTNODE=record
           ATTNO1:1..NOATTS;
           NEXTATT:PTR1
         end;
 SORTNODE=record
           ATTNOS:1..NOATTS;
           SORDER:UPDOWN;
           NEXTSORT:^SORTNODE
          end;
 TUPLE=record
         FIELD:array[1..NOATTS] of integer;
         MARK:boolean;
         NXTPL:^TUPLE
       end;
 PTUPLE=^TUPLE;
 RELATION=record
           RELNAMED:ALFA;
           ATTD:array[1..NOATTS] of 0..NOATTS;
           KEYD:array[1..NOATTS] of 0..NOATTS;
           FRSTPL:^TUPLE;
           NTPLS:integer;
           RELFL:ALFA
          end;
 CONDCODE=1..9;
 TYPEOFID1=IDENT..REALNUMBER;
 ATTRIBUTE=record
           ATTNAMED:ALFA;
           TYPEATT:TYPEOFID1
          end;
 TYPEOFID8=INTNUMBER..REALNUMBER;
 CONDITION=record
           RELNOC:1..NORELSP;
           ATTNOC:0..NOATTS;
           COND:EQL..GEQ;
           case CNDCD:CONDCODE of
                1:(case TOID1:TYPEOFID1 of
                     IDENT:(VALIA:ALFA);
                     INTNUMBER:(VALII:integer);
                     REALNUMBER:(VALIR:real));
                4,5,6,7:(VAL4:integer);
                7:(RELNO7:1..NORELSP;
                   ATTNO7:1..NOATTS);
                8:(SATTS8:PTR1;
                   TATTS:1..NOATTS;
                   case TOID8:TYPEOFID8 of
                   INTNUMBER:(VAL8I:integer);
                   REALNUMBER:(VAL8R:real));
                9:(SATTS9:PTR1;
                   DATTS9:PTR1;
                   VAL9:integer)
           end;
 ATTSUSED=record
           ATTNOT:0..NOATTS;
           RELNOT:0..NORELSP;
           ACTCD:0..99
          end;
```

FIGURE 4.16 MARK PROGRAM (CONTD.)

```
ACTION=record
            SRTREQ:boolean;
            PSORT:^SORTNODE;
            ITLPEQ:boolean;
            IREL:1..NORELSP;
            SATTS:PTR1;
            IATT:1..NOATTS;
            COUNTREQ:boolean;
            LMTREQ:boolean;
            LIMNO:integer
          end;
GAMA=record
          GAMASYM:SYMBOL;
          GAMAVAL:integer;
          NEXTGAMA:^GAMA
        end;
var
SYM,TEMPSYM:SYMBOL;
ID,ASPACE:ALFA;
EPR,INTNUM,I,J,K,L,M,N,KOUNT,CN,R1,R2,TOTAL:integer;
FLAG:boolean;
P,REALNUM:real;
KK:0..AL;
F:TEXT;
CH,TEMPCH:char;
CC,LL:0..121;
WORD:array[1..NORW] of ALFA;
WSYM:array[1..NORW] of SYMBOL;
SSYM:array[char] of SYMBOL;
LINE:array[0..121] of char;
RELDIR:array[1..NORELSP] of RELATION;
ATTDIR:array[1..NOATTS] of ATTRIBUTE;
CONTAB:array[1..5] of CONDITION;
P1,P11:PTR1;
ACTTAB:ACTION;
RELNO:0..NORELSP;
ATTNO:0..NOATTS;
TABATT:array[1..NOATTS] of ATTSUSED;
SP1,SP11:^SORTNODE;
TEMPSORT:UPDOWN;
CONREL:array[1..NORELSP,1..NORELSP] of 0..NORELS;
CONATT:array[1..NORELSP,1..NORELSP] of 0..NOATTS;
IREL:1..NORELSP;
GP1,GP2,GP3,GP4:^GAMA;
TPL1,TPL2,TPL3,TPL4:^TUPLE;
TABLE:array[1..NOATTS] of array[1..10] of ALFA;
procedure INITIALIZE;
PROCEDURE HALT;
PROCEDURE ERROR(N:INTEGER);
PROCEDURE WARN(N:INTEGER);
PROCEDURE GETNAME(ID:ALFA);
PROCEDURE DEFINEATTS;
procedure GETATTNO(var N:integer;ID:ALFA);
procedure READATTS;
function SEARCH(N:integer;ID:ALFA):integer;
procedure DEFINERELS;
procedure GETRELNO(var N:integer;ID:ALFA);
procedure READRELS;
procedure BLDCONTABS;
procedure GETNEXTSYM;
procedure CLEARTABLES;
procedure CHECKQUERY;
procedure RUNQUERY;
procedure MODCONTAB;
procedure OUTREL(R:integer);
```

FIGURE A.18 MAIN PROGRAM

```
ACTION=record
            SRTREQ:boolean;
            PSORT:^SORTNODE;
            ITLREQ:boolean;
            IREL:1..NORELSP;
            SATTS:PTR1;
            IATT:1..NOATTS;
            COUNTREQ:boolean;
            DETREQ:boolean;
            LINNO:integer
          end;
GAMA=record
        GAMASYM:SYMBOL;
        GAMAVAL:integer;
        NEXTGAMA:^GAMA
      end;
var
SYM,TEMPSYM:SYMBOL;
ID,A,WSPACE:ALFA;
ERR,INTMIN,I,J,K,L,M,N,KOUNT,CN,R1,R2,TOTAL:integer;
FLAG:boolean;
P,REALNUM:real;
KK:0..AL;
F:TEXT;
CH,TEMPCH:char;
CC,LL:0..121;
WORD:array[1..NORW] of ALFA;
WKYM:array[1..NORW] of SYMBOL;
SSYM:array[char] of SYMBOL;
LINE:array[0..121] of char;
RELCIR:array[1..NORELSP] of RELATION;
ATTDIR:array[1..NOATTS] of ATTRIBUTE;
CONTAB:array[1..5] of CONDITION;
P1,P11:PTR1;
ACTTAB:ACTION;
RELNO:0..NORELSP;
ATTNO:0..NOATTS;
TABATT:array[1..NOATTS] of ATTSUSED;
SP1,SP11:^SORTNODE;
TEMPSORT:UPDOWN;
COMPEL:array[1..NORELSP,1..NORELSP] of 0..NORELS;
COMATT:array[1..NORELSP,1..NORELSP] of 0..NOATTS;
IREL:1..NORELSP;
GP1,GP2,GP3,GP4:^GAMA;
TPL1,TPL2,TPL3,TPL4:^TUPLE;
TAB:array[1..NOATTS] of array[1..101] of ALFA;
procedure INITIALIZE;
PROCEDURE HALT;
PROCEDURE ERROR(N:INTEGER);
PROCEDURE WARN(N:INTEGER);
PROCEDURE GETNAME(ID:ALFA);
PROCEDURE DEFINEATTS;
procedure GETATTNO(var N:integer;ID:ALFA);
procedure READATTS;
function SEARCH(N:integer;ID:ALFA):integer;
procedure DEFINERELS;
procedure GETRELNO(var N:integer;ID:ALFA);
procedure READRELS;
procedure BLDCONTABS;
procedure GETNEXTSYM;
procedure CLEARTABLES;
procedure CHECKQUERY;
procedure RUNQUERY;
procedure MDFCONTAB;
procedure OUTREL(R:integer);
```

FIGURE 4.18 MAIN PROGRAM (CONTD..)

```
begin
 INITIALIZE;
 DEFINEATTS;
 READATTS;
 DEFINERELS;
 READRELS;
 BLDCOMTABS;
 WRITELN;
 GETNEXTSYM;
 while SYM=IDENT do
  begin
   if IREL>NORELS then MDFCOMTAB;
   CLEARTABLES;
   CHECKQUERY;
   WRITELN;
   if ERR=0 then
    begin WRITELN('Query is O.K.');
     for A:=1 to 60 do WRITE('*');
     WRITELN;
     RUNQUERY
    end
   else WRITELN(ERR:3,' Errors in query.')
  end;
 if SYM=SEMICOLON then WARN(1);
 if ERR=0 then OUTREL(IRFL);
 WRITELN
end.
```

FIGURE 4.16 Main PROGRAM

of each of the example queries considered in Chapter III (Query1 through Query9). One more query has been included to show that the system works satisfactorily for a multi-step query also. The word statement of this query is -

Query_10 Find the names of those suppliers who supply atleast all those jobs that are supplied to by supplier 'Smith'

In our language, this will be written as -

```
QUERY10(W1)
CONDITION : SUPPLIER.SNAME = "SMITH"
ACTION : GET SUPPLY.J#
QUERY10(W)
CONDITION : W1.J# = ALL
ACTION : GET SUPPLIER.SNAME;
```

The output of this example query is given in Fig. 4.17.

```
QUERY1( )
CONDITION:PART.QOH<"5"
ACTION:GET(3) PART.PNAME,PART.QOH;

Query is O.K.
*************************************************************
%TEMP1      = PROJECT PART        BY PNAME      QOH
Truncate %TEMP1      keeping only the first  3 tuples.
%           = %TEMP1
Display %             with proper formatting.
*************************************************************

            PNAME       QOH
            -----       ---

            NUT          4
            SCREW        3
            CAM          2

*************************************************************
```

```
QUERY2(W)
CONDITION:PART.QOH=1 TOP
ACTION:GET PART.P#,PART.PNAME;

Query is O.K.
*************************************************************
Find the   1th  highest value of QOH        in PART
%TEMP1      = PROJECT PART        BY P#         PNAME
%           = %TEMP1
Display %             with proper formatting.
*************************************************************

            P#          PNAME
            --          -----

             4          SCREW

*************************************************************
```

FIGURE 4.17 EXAMPLE QUERIES (CONT

```
QUERY3(*)
CONDITION:SUPPLY.P#=*
ACTION:GET PART.PNAME,PART.QOH(UP PART.QOH);

Query is O.K.:
*****************************************************

WTEMP1      = JOIN of PART        and SUPPLY      on P#

WTEMP2      = PROJECT WTEMP1      BY PNAME        QOH
Sort WTEMP2     on  ascending QOH

*           = WTEMP2
Display *           with proper formatting.
*****************************************************
```

| PNAME | QOH |
|---|---|
| COG | 1 |
| CAM | 2 |
| SCREW | 3 |
| NUT | 4 |
| BOLT | 7 |
| SCREW | 9 |

```
*****************************************************

QUERY4(*)
CONDITION:COUNT(SUPPLY SAME P# DIFFERENT J#)>2
ACTION:GET(COUNT) SUPPLY.P#;

Query is O.K.:
*****************************************************

WTEMP1      = PROJECT SUPPLY      BY P#
Find the number of tuples in WTEMP1     and store in (KOUNT).

*           = WTEMP1
*****************************************************

Number of tuples in output relation is          3

*****************************************************
```

FIGURE 4.17 EXAMPLE QUERIES (CONT)

```
QUERY5(W)
CONDITION:TOTAL(SUPPLY SAME P#,J#:QTY)>5
ACTION:GET SUPPLY.P#,SUPPLY.J#,TOTAL(SUPPLY SAME P#,J#:QTY);

Query is O.K.
*****************************************************

WTEMP1      = PROJECT SUPPLY      BY P#          J#          QTY
              -------             --
In WTEMP1     do totalling of QTY        with same P#          J#
W           = WTEMP2
Display W         with proper formatting.
*****************************************************
```

| P# | J# | QTY |
|---|---|---|
| 1 | 4 | 7 |
| 3 | 1 | 6 |
| 3 | 5 | 6 |
| 3 | 7 | 8 |

```
*************************************************************
```

```
QUERY6(W)
CONDITION:JOB.J#=ALL
ACTION:GET SUPPLIER.SNAME,SUPPLIER.LOC;

Query is O.K.
*****************************************************

WTEMP1      = JOIN of SUPPLIER    and SUPPLY     on S#
              -------             ---            --

WTEMP2      = JOIN of JOB         and WTEMP1     on J#
              -------             ---            --

WTEMP3      = PROJECT WTEMP2      BY SNAME       LOC         J#
              -------             --

WTEMP4      = PROJECT JOB         BY J#
              -------             --

WTEMP5      = DIVIDE WTEMP3       BY WTEMP4
              ------              --

W           = WTEMP5
Display W         with proper formatting.
*****************************************************
```

| SNAME | LOC |
|---|---|
| JONES | PARIS |

```
*************************************************************
```

FIGURE 4.17 EXAMPLE QUERIES (CONTI

```
QUERY5(W)
CONDITION:TOTAL(SUPPLY SAME P#,J#:QTY)>5
ACTION:GET SUPPLY.P#,SUPPLY.J#,TOTAL(SUPPLY SAME P#,J#:QTY);

Query is O.K.
*****************************************************

WTEMP1      = PROJECT SUPPLY      BY P#          J#          QTY
              -------             --
In WTEMP1     do totalling of QTY        with same P#          J
W           = TEMP2
Display W             with proper formatting.
*****************************************************


            P#          J#          QTY
            --          --          ---

             1           4           7
             3           1           6
             3           5           6
             3           7           8


*************************************************************


QUERY6(W)
CONDITION:JOB.J#=ALL
ACTION:GET SUPPLIER.SNAME,SUPPLIER.LOC;

Query is O.K.
*****************************************************

WTEMP1      = JOIN of SUPPLIER    and SUPPLY     on S#
              -------             ---            --

WTEMP2      = JOIN of JOB         and WTEMP1     on J#
              -------             ---            --

WTEMP3      = PROJECT WTEMP2      BY SNAME       LOC         J#
              -------             --

WTEMP4      = PROJECT JOB         BY J#
              -------             --

WTEMP5      = DIVIDE WTEMP3       BY WTEMP4
              ------              --

            = WTEMP5
Display W             with proper formatting.
*****************************************************


            SNAME       LOC
            -----       ---

            JONES       PARIS


*****************************************************
```

FIGURE 4.17 EXAMPLE QUERIES

```
QUERY,TEST 1:SUPPLIER.S#<>SUPPLY.S#
ACTION:GET SUPPLIER.SNAME,SUPPLIER.LOC;

Query is O.K..
*************************************************************

WTEMP1      = PROJECT SUPPLIER    BY S#
WTEMP2      = PROJECT SUPPLY      BY S#
WTEMP3      = DIFFERENCE OF WTEMP1      AND WTEMP2
WTEMP4      = JOIN of SUPPLIER    and WTEMP3      on S#
WTEMP5      = PROJECT WTEMP4      BY SNAME      LOC
W           = WTEMP5
Display W          with proper formatting.
*************************************************************

            SNAME       LOC

            CLARK       LONDON

*************************************************************
```

FIGURE 4.17 EXAMPLE QUERIES (CONTD)

```
QUERY8(4)
CONDITION:SUPPLIER.LOC="ATHENS" AND SUPPLY.J#="4"
ACTION:GET SUPPLIER.SNAME,SUPPLIER.LOC;

Query is O.K.
*************************************************

WTEMP1      = JOIN of SUPPLIER   and SUPPLY    on S#

WTEMP2      = PROJECT WTEMP1     BY SNAME      LOC

WTEMP3      = PROJECT SUPPLIER   BY SNAME      LOC

WTEMP4      = INTERSECTION OF WTEMP2     and WTEMP3

W           = WTEMP4
Display W          with proper formatting.
*************************************************

            SNAME       LOC

            ADAMS       ATHENS

*************************************************
```

FIGURE 4.17 EXAMPLE QUERIES (CONTI

```
QUERY5(v)
CONDITION:SUPPLIER.LOC="ATHENS" AND SUPPLY.J#="4"
ACTION:GET SUPPLIER.SNAME,SUPPLIER.LOC;

Query is O.K.
*****************************************************

WTEMP1      = JOIN of SUPPLIER   and SUPPLY    on S#

WTEMP2      = PROJECT WTEMP1     BY SNAME      LOC

WTEMP3      = PROJECT SUPPLIER   BY SNAME      LOC

WTEMP4      = INTERSECTION OF WTEMP2     and WTEMP3

W           = WTEMP4
Display W          with proper formatting.
*****************************************************

            SNAME       LOC

            ADAMS       ATHENS

*****************************************************
```

FIGURE 4.17 EXAMPLE QUERIES (CONT

```
QUERY9(W)
CONDITION:PART.COLOR="BLUE" OR PART.COLOR="GREEN"
ACTION:GET SUPPLIER.SNAME,SUPPLIER.LOC;

Query is O.K.
*************************************************

WTEMP1      = JOIN of SUPPLIER    and SUPPLY     on S#
              -------             ---            --

WTEMP2      = JOIN of PART        and WTEMP1     on P#
              -------             ---            --

WTEMP3      = PROJECT WTEMP2      BY SNAME       LOC
              -------             --

WTEMP4      = JOIN of SUPPLIER    and SUPPLY     on S#
              -------             ---            --

WTEMP5      = JOIN of PART        and WTEMP4     on P#
              -------             ---            --

WTEMP6      = PROJECT WTEMP5      BY SNAME       LOC
              -------             --
WTEMP7      = UNION OF WTEMP3      and WTEMP6
              ----- --              ---

W           = WTEMP7
Display W              with proper formatting.
*************************************************

            SNAME       LOC
            -----       ---

            ADAMS       ATHENS
            JONES       PARIS
            BLAKE       PARIS

*************************************************
```

FIGURE 4.17 EXAMPLE QUERIES

CONTD.

```
QUERY10(3)
CONDITION:SUPPLIER.SNAME="SMITH"
ACTION:GET SUPPLY.J#
QUERY3(J1)

Query is O.K.:
*************************************************************

WTEMP1      = JOIN of SUPPLY      and SUPPLIER    on S#

WTEMP2      = PROJECT WTEMP1      BY J#

W1          = WTEMP2
CONDITION:W.J#=ALL
ACTION:GET SUPPLIER.SNAME,SUPPLIER.LOC;

Query is O.K.:
*************************************************************

WTEMP3      = JOIN of SUPPLIER    and SUPPLY      on S#

WTEMP4      = JOIN of W           and WTEMP3      on J#

WTEMP5      = PROJECT WTEMP4      BY SNAME        LOC         J#

WTEMP6      = PROJECT W           BY J#

WTEMP7      = DIVIDE WTEMP5       BY WTEMP6

W1          = WTEMP7
Display W1          with proper formatting.
*************************************************************
```

| SNAME | LOC |
|---|---|
| SMITH | LONDON |
| JONES | PARIS |

*************************************************************

FIGURE 4.17 EXAMPLE QUERIES

# CHAPTER V

## IMPLEMENTATION OF ALGEBRAIC EXPRESSIONS

So far we have converted the source query into expressions in the relational algebra. These expressions consist of the following operations -

JOIN
PROJECT
DIVIDE
FIND DIFFERENCE
SORT
FIND N-TH VALUE
COUNT NUMBER OF TUPLES
DO TOTALLING
AND TRUNCATE

We now give the algorithms for implementing each of these operations on relations. It has to be pointed out here that, at present, no efficient algorithms exist for carrying out these operations. The efficiency of the existing algorithms depends upon the complexity with which data is stored in the system. A more complex storage, involving the maintenance of lists, pointers, secondary indexes etc., could result in faster algorithms for these operations as the access times would be considerably reduced. But a complex storage structure has the disadvantage of making the task of deleting/updating/inserting more complicated. For our algorithms we assume that

the relations are stored as a list of tuples in the main memory of the computer. All relations, including the intermediate relations, hence, have to be searched sequentially. The idea of giving these algorithms is just to show that the language we have described produces correct results.

5.1 Join:

This operation is invoked through a call to the procedure JOIN (R1, A, R2), where R1 and R2 are the numbers of the relations to be joined on the common attribute A. The lists of tuples in R1 and R2, pointed at by RELDIR [R1].FRSTPL and RELDIR [R2].FRSTPL respectively, are searched sequentially and whenever there is a match found for the values of attribute A in a tuple in R1 and a tuple in R2 then the two tuples are catenated and written into a new tuple which is added to the list of tuples in the new relation being created. Ofcourse, one of the values of the attribute A is omitted in the process. The value of IREL, the pointer to the latest relation in the system, is increased and RELDIR[IREL].FRSTPL is made to point to the first tuple in the newly created relation. A listing of the procedure JOIN is given in Fig. 5.1.

5.2 Project:

This operation is invoked by a call to the procedure PROJECT(R,PATR), where R is the number of the relation to be projected by the attributes whose numbers are in the list

```
procedure JOIN(R1,A,R2:integer);
  var
   I,J1,J2,K,VAL:integer;
   TPL1,TPL2,TPL3,TPL4:^TUPLE;
  begin IREL:=IREL+1;
   GIVENAME;
   WRITE(RELDIR[IREL].RELNAMED:AL,' = JOIN of ');
   WRITE(RELDIR[R1].RELNAMED:AL);
   WRITE(' and ',RELDIR[R2].RELNAMED:AL,' on ');
   WRITELN(ATTDIR[A].ATTNAMED:AL);
   WRITELN('--------':20,'---':15,'--':14);
   WRITELN;
   J1:=1;
   while RELDIR[R1].ATTD[J1]#A do J1:=J1+1;
   J2:=1;
   while RELDIR[R2].ATTD[J2]#A do J2:=J2+1;
   I:=1;
   while RELDIR[R1].ATTD[I]#0 do
    begin RELDIR[IREL].ATTD[I]:=RELDIR[R1].ATTD[I];
     I:=I+1;
    end;
   K:=1;
   while RELDIR[R2].ATTD[K]#0 do
    begin
     if RELDIR[R2].ATTD[K]#A then
      begin RELDIR[IREL].ATTD[I]:=RELDIR[R2].ATTD[K];
       I:=I+1;
       K:=K+1
      end
     else K:=K+1
    end;
   TPL1:=RELDIR[R1].FRSTPL;
   NEW(TPL3);
   RELDIR[IREL].FRSTPL:=TPL3;
   while TPL1#nil do
    begin VAL:=TPL1^.FIELD[J1];
     TPL2:=RELDIR[R2].FRSTPL;
     while TPL2#nil do
      begin
       if TPL2^.FIELD[J2]=VAL then
        begin TPL4:=TPL3;
         NEW(TPL3);
         TPL4^.NXTPL:=TPL3;
         I:=1;
         while RELDIR[R1].ATTD[I]#0 do
          begin TPL4^.FIELD[I]:=TPL1^.FIELD[I];
           I:=I+1
          end;
         K:=1;
         while RELDIR[R2].ATTD[K]#0 do
          begin
           if RELDIR[R2].ATTD[K]#A then
            begin TPL4^.FIELD[I]:=TPL2^.FIELD[K];
             I:=I+1;
             K:=K+1
            end
           else K:=K+1
          end
        end;
       TPL2:=TPL2^.NXTPL
      end;
     TPL1:=TPL1^.NXTPL
    end;
   if RELDIR[IREL].FRSTPL=TPL3 then RELDIR[IREL].FRSTPL:=nil
   else TPL4^.NXTPL:=nil
  end;
```

FIGURE 5.1 PROCEDURE JOIN

pointed at by PATR. As described in 4.6, the projection operation would be of different types depending upon the condition type (CNDCD).

For CNDCD = 1,4 and 5, this operation would be;

PROJECT R BY (attributes pointed at by PATR) WHERE AC <COND> value

For CNDCD = 2,3 and 7, this operation would be :

PROJECT R BY (attributes pointed at by PATR).

For CNDCD = 8, this operation would be :

PROJECT R BY (attributes pointed at by PATR) WHERE (total of attribute TATT8 with same SATTS8)<COND> VAL8I.

And for CNDCD = 9, this operation would be :

PROJECT R BY (attributes pointed at by PATR) WHERE (number of tuples with same SATTS9 and different DATTS9)<COND> VAL9.

For all the four types of project operations, the list of tuples, pointed at by RELDIR[R].FRSTPL, is searched sequentially and each time a tuple is found which satisfies the constraint (if any) it is projected out into another tuple, copying only values of those attributes which are there in the list PATR. Each time a new tuple is created, it is appended to the list of tuples pointed at by RELDIR[IREL].FRSTPL, where IREL has been incremented in the beginning of the procedure. A procedure TRNSFR(TPL1,TPL2) is employed to transfer the required attribute values from tuple TPL1 into tuple TPL2. A boolean function STSFD(VAL1,VAL2) checks if

'VAL1 <COND> VAL2' is satisfied. A listing of the procedure PROJECT, procedure TRNSFR and function STSFD is given in Fig. 5.2.

5.3 Division:

This operation is invoked through a call to the procedure DIVIDE(R1,R2), where R1 is the number of the relation which is to be divided by relation whose number is R2. In this case R2 is a unary relation and relation R1 has the attribute of R2 at the end in its list of attributes. Because there is no duplication allowed in a relation, a tuple 'X' will appear in the output list if and only if 'X' is found in R1 as many times as there are tuples in R2. Thus the procedure is similar to that for PROJECT (for CNDCD=9), except that instead of VAL9, this procedure uses KOUNT1, which is equal to the number of tuples in R2. A listing of the procedure DIVIDE is given in Figure 5.3. As usual IREL is incremented in the beginning of the procedure and RELDIR[IREL].FRSTPL points at the list of the tuples in the newly created relation.

5.4 Other Operations:

The remaining operations are relatively simpler and are described below briefly.

5.4.1 Find Difference:

This operation is invoked through a call to the procedure SUBTRACT(R1,R2), where relation R2 is to be subtracted from

```
procedure PROJECT(R:integer;PATR:PTR1);
  var
   I,J,K,J1,JT,TEMP,KOUNT:integer;
   P:PTR1;
   FLAG:boolean;
   TPL1,TPL2,TPL3:^TUPLE;
   J3,JD:array[1,.NOATTS] of integer;
  function STSFD(VAL1,VAL2:integer):boolean;
    begin STSFD:=false;
     case CONTAB[CN].COND of
        EQL:
          if VAL1=VAL2 then STSFD:=true;
        NEQ:
          if VAL1#VAL2 then STSFD:=true;
        LEQ:
          if VAL1<=VAL2 then STSFD:=true;
        GEQ:
          if VAL1>=VAL2 then STSFD:=true;
        LSS:
          if VAL1<VAL2 then STSFD:=true;
        GTR:
          if VAL1>VAL2 then STSFD:=true
     end
    end;
  procedure TRNSFR(TPL1,TPL2:PTUPLE);
    var
     I:integer;
    begin I:=1;
     while JP[I]#0 do
      begin TPL2^.FIELD[I]:=TPL1^.FIELD[JP[I]];
       I:=I+1
      end
    end;
  begin IREL:=IREL+1;
   GIVENAME;
   WRITE(RELDIR[IREL].RELNAMED:AL,' = PROJECT ');
   WRITE(RELDIR[R].RELNAMED:AL,' BY ');
   P:=PATR;
   I:=1;
   repeat J:=P^.ATTNOL;
     RELDIR[IREL].ATTD[I]:=J;
     WRITE(ATTDIR[J].ATTNAMED:AL,' ');
     K:=1;
     while RELDIR[R].ATTD[K]#J do K:=K+1;
     JP[I]:=K;
     P:=P^.NEXTATT;
     I:=I+1
   until P=nil;
   for K:=I to NOATTS do JP[K]:=0;
   WRITELN;
   WRITELN('-------':20,'--':14);
   with CONTAB[CN] do
   case CONCD of
     1:
        begin TPL1:=RELDIR[R].FRSTPL;
         J1:=1;
         while RELDIR[R].ATTD[J1]#AC do J1:=J1+1;
         NEW(TPL2);
         RELDIR[IREL].FRSTPL:=TPL2;
         while TPL1<>nil do
          begin
           if STSFD(TPL1^.FIELD[J1],VAL1) then
            begin TPL3:=TPL2;
             NEW(TPL2);
             TPL3^.NXTPL:=TPL2;
             TRNSFR(TPL1,TPL3)
            end;
           TPL1:=TPL1^.NXTPL
          end;
         if RELDIR[IREL].FRSTPL=TPL2 then RELDIR[IREL].FRSTPL:=nil
         else TPL3^.NXTPL:=nil
        end;
```

FIGURE 5.2 PROCEDURE PROJECT

(CONTD...)

```
2,3,7:
    begin TPL1:=RELDIR[R].FRSTPL;
     NEW(TPL2);
     RELDIR[IREL].FRSTPL:=TPL2;
     while TPL1<>nil do
      begin TPL3:=TPL2;
       NEW(TPL2);
       TPL3^.NXTPL:=TPL2;
       TRNSFR(TPL1,TPL3);
       TPL1:=TPL1^.NXTPL
      end;
     if RELDIR[IREL].FRSTPL=TPL2 then
       RELDIR[IREL].FRSTPL:=nil
     else TPL3^.NXTPL:=nil
    end;
6:
    begin TPL1:=RELDIR[R].FRSTPL;
     I:=0;
     P:=SATIS8;
     while P<>nil do
      begin I:=I+1;
       K:=1;
       while RELDIR[R].ATTD[K]<>P^.ATTNOL do K:=K+1;
       JS[I]:=K;
       P:=P^.NEXTATT
      end;
     for K:=I+1 to NOATTS do JS[K]:=0;
     JT:=1;
     while RELDIR[R].ATTD[JT]<>TATT8 do JT:=JT+1;
     NEW(TPL3);
     RELDIR[IREL].FRSTPL:=TPL3;
     while TPL1<>nil do
      begin
       if TPL1^.MARK then
        begin TPL1^.MARK:=false;
         TPL1:=TPL1^.NXTPL
        end
       else
        begin TOTAL:=TPL1^.FIELD[JT];
         TPL2:=TPL1^.NXTPL;
         while TPL2<>nil do
          begin
           if not (TPL2^.MARK) then
            begin I:=1;
             K:=JS[1];
             FLAG:=true;
             while (FLAG and (K<>0)) do
              begin
               if TPL1^.FIELD[K]<>TPL2^.FIELD[K] then
                FLAG:=false
               else
                begin I:=I+1;
                 K:=JS[I]
                end
              end;
             if FLAG then
              begin TOTAL:=TOTAL+TPL2^.FIELD[JT];
               TPL2^.MARK:=true
              end
            end;
           TPL2:=TPL2^.NXTPL
          end;
```

FIGURE 5.2 PROCEDURE PROJECT (CONTD.)

```
        if STSFD(TOTAL,VAL8I) then
         begin TPL4:=TPL3;
          NEW(TPL3);
          TPL4^.NXTPL:=TPL3;
          TRNSFR(TPL1,TPL4);
          TPL2:=TPL1^.NXTPL;
          while TPL2<>nil do
           begin
            if TPL2^.MARK then
             begin I:=1;
              K:=JS[I];
              FLAG:=true;
              while (FLAG and(K<>0)) do
               begin
                if TPL1^.FIELD[K]<>TPL2^.FIELD[K] then
                 FLAG:=false
                else
                 begin I:=I+1;
                  K:=JS[I]
                 end
               end;
              if FLAG then
               begin TPL4:=TPL3;
                NEW(TPL3);
                TPL4^.NXTPL:=TPL3;
                TRNSFR(TPL2,TPL4)
               end
             end;
            TPL2:=TPL2^.NXTPL
           end
         end;
        TPL1:=TPL1^.NXTPL
       end
     end;
    if RELDIR[IREL].FRSTPL=TPL3 then RELDIR[IREL].FRSTPL:=nil
    else TPL4^.NXTPL:=nil
   end;
9: begin I:=0;
    P:=SATTS9;
    while P<>nil do
     begin I:=I+1;
      K:=1;
      while RELDIR[R].ATTD[K]<>P^.ATTNOL do K:=K+1;
      JS[I]:=K;
      P:=P^.NEXTATT
     end;
    for K:=I+1 to NOATTS do JS[K]:=0;
    I:=0;
    P:=DATTS9;
    while P<>nil do
     begin I:=I+1;
      K:=1;
      while RELDIR[R].ATTD[K]<>P^.ATTNOL do K:=K+1;
      JD[I]:=K;
      P:=P^.NEXTATT
     end;
    for K:=I+1 to NOATTS do JD[K]:=0;
    NEW(TPL3);
    RELDIR[TRPL].FRSTPL:=TPL3;
```

FIGURE 5.4 PROCEDURE PROJECT (CONTD.)

```
        TPL1:=RELDIR[R].FRSTPL;
        while TPL1<>nil do
         begin
          if TPL1^.MARK then
           begin TPL1^.MARK:=false;
            TPL1:=TPL1^.NXTPL
           end
          else
           begin KOUNT:=1;
            TPL2:=TPL1^.NXTPL;
            while TPL2<>nil do
             begin
              if not(TPL2^.MARK) then
               begin I:=1;
                K:=JS[I];
                FLAG:=true;
                while (FLAG and (K<>0)) do
                 begin
                  if TPL1^.FIELD[K]<>TPL2^.FIELD[K] then
                   FLAG:=false
                  else
                   begin I:=I+1;
                    K:=JS[I]
                   end
                 end;
                if FLAG then
                 begin I:=1;
                  K:=JD[I];
                  FLAG:=false;
                  while not(FLAG or(K=0)) do
                   begin
                    if TPL1^.FIELD[K]=TPL2^.FIELD[K] then
                     FLAG:=true
                    else
                     begin I:=I+1;
                      K:=JD[I]
                     end
                   end;
                  if not FLAG then
                   begin KOUNT:=KOUNT+1;
                    TPL2^.MARK:=true
                   end
                 end
               end;
              TPL2:=TPL2^.NXTPL
             end;
            if STSFD(KOUNT,VAL9) then
             begin TPL4:=TPL3;
              NEW(TPL3);
              TPL4^.NXTPL:=TPL3;
              TRNSFR(TPL1,TPL4)
             end;
            TPL1:=TPL1^.NXTPL
           end
         end;
        if RELDIR[IREL].FRSTPL=TPL3 then RELDIR[IREL].FRSTPL:=nil
        else TPL4^.NXTPL:=nil
       end
  end
end;
```

FIGURE 5.2 PROCEDURE PROJECT

```
        TPL1:=RELDIR[R].FRSTPL;
        while TPL1#nil do
         begin
          if TPL1^.MARK then
           begin TPL1^.MARK:=false;
            TPL1:=TPL1^.NXTPL
           end
          else
           begin KOUNT:=1;
            TPL2:=TPL1^.NXTPL;
            while TPL2#nil do
             begin
              if not(TPL2^.MARK) then
               begin I:=1;
                K:=JS[I];
                FLAG:=true;
                while (FLAG and (K#0)) do
                 begin
                  if TPL1^.FIELD[K]#TPL2^.FIELD[K] then
                   FLAG:=false
                  else
                   begin I:=I+1;
                    K:=JS[I]
                   end
                 end;
                if FLAG then
                 begin I:=1;
                  K:=JD[I];
                  FLAG:=false;
                  while not(FLAG or(K=0)) do
                   begin
                    if TPL1^.FIELD[K]=TPL2^.FIELD[K] then
                     FLAG:=true
                    else
                     begin I:=I+1;
                      K:=JD[I]
                     end
                   end;
                  if not FLAG then
                   begin KOUNT:=KOUNT+1;
                    TPL2^.MARK:=true
                   end
                 end
               end;
              TPL2:=TPL2^.NXTPL
             end;
            if STSFD(KOUNT,VAL9) then
             begin TPL4:=TPL3;
              NEW(TPL3);
              TPL4^.NXTPL:=TPL3;
              TRNSFR(TPL1,TPL4)
             end;
            TPL1:=TPL1^.NXTPL
           end
         end;
        if RELDIR[IREL].FRSTPL=TPL3 then RELDIR[IREL].FRSTPL:=nil
        else TPL4^.NXTPL:=nil
       end
  end
end;
```

FIGURE 5.2 PROCEDURE PROJECT

```
procedure DIVIDE(R1,R2:integer);
  var
   I,KOUNT1,KOUNT2:integer;
   TPL1,TPL2,TPL3,TPL4:^TUPLE;
   FLAG:boolean;
  begin IREL:=IREL+1;
   GIVENAME;
   WRITE(RELDIR[IREL].RELNAMED:AL,' = DIVIDE ');
   WRITE(RELDIR[R1].RELNAMED:AL);
   WRITELN(' BY ',RELDIR[R2].RELNAMED:AL);
   WRITELN('------':19,'--':14);
   WRITELN;
   NEW(TPL3);
   RELDIR[IREL].FRSTPL:=TPL3;
   TPL1:=RELDIR[R2].FRSTPL;
   KOUNT1:=0;
   while TPL1<>nil do
    begin KOUNT1:=KOUNT1+1;
     TPL1:=TPL1^.NXTPL
    end;
   I:=1;
   while RELDIR[R1].ATTD[I]<>RELDIR[R2].ATTD[1] do
    begin RELDIR[IREL].ATTD[I]:=RELDIR[R1].ATTD[I];
     I:=I+1
    end;
   TPL1:=RELDIR[R1].FRSTPL;
   while TPL1<>nil do
    begin
     if TPL1^.MARK then
      begin TPL1^.MARK:=false;
       TPL1:=TPL1^.NXTPL
      end
     else
      begin KOUNT2:=1;
       TPL2:=TPL1^.NXTPL;
       while TPL2<>nil do
        begin
         if not(TPL2^.MARK) then
          begin I:=1;
           FLAG:=true;
           while (FLAG and(RELDIR[IREL].ATTD[I]<>0)) do
            begin
             if TPL1^.FIELD[I]<>TPL2^.FIELD[I] then FLAG:=false
             else I:=I+1
            end;
           if FLAG then
            begin KOUNT2:=KOUNT2+1;
             TPL2^.MARK:=true
            end
          end;
         TPL2:=TPL2^.NXTPL
        end;
       if KOUNT1=KOUNT2 then
        begin TPL4:=TPL3;
         NEW(TPL3);
         TPL4^.NXTPL:=TPL3;
         I:=1;
         while RELDIR[IREL].ATTD[I]<>0 do
          begin TPL4^.FIELD[I]:=TPL1^.FIELD[I];
           I:=I+1
          end
        end;
       TPL1:=TPL1^.NXTPL
      end
    end;
   if RELDIR[IREL].FRSTPL=TPL3 then RELDIR[IREL].FRSTPL:=nil
   else TPL4^.NXTPL:=nil
  end;
```

FIGURE 5.2 PROCEDURE DIVIDE

relation R1. Both of these relations are unary and have the same attribute in them. The list of tuples pointed at by RELDIR[R1].FRSTPL is traversed through sequentially. For each of the tuples in the list, the list of tuples pointed at by RELDIR[R2].FRSTPL is searched to see if the tuple in R1 is present in R2. In case a tuple in R1 is present in R2 also then the tuple is removed from the list in R1. Finally IREL is incremented and RELDIR[IREL].FRSTPL is made to point to the first tuple of the remaining tuples in R1. A listing of the procedure SUBTRACT is given in Fig. 5.4.

5.4.2 Find n-th Value:

This operation is invoked through a call to the procedure FINDNTH(R,A,N,FLAG), where the N-th value (from top if FLAG is true and from bottom if FLAG is false) of attribute A in relation R is to be found. The list of tuples in R is traversed through N times and each time the tuple with the maximum (or minimum) value is marked. The tuple which is marked in the end contains the value in which we are interested. This value is copied into the condition table CONTAB[CN].VAL1 (integer or real as the case may be). Finally th list of tuples is tra-. versed once again and all the tuples are unmarked. A listing of the procedure FINDNTH is given in Figure 5.4.

```
procedure SUBTRACT(R1,R2:integer);
  var
   TPL1,TPL2,TPL3:^TUPLE;
   FLAG:boolean;
  begin
   repeat TPL3:=RELDIR[R2].FRSTPL;
     FLAG:=false;
     while not(FLAG or (TPL3=nil)) do
       if TPL3^.FIELD[1]=RELDIR[R1].FRSTPL^.FIELD[1] then
        FLAG:=true
       else TPL3:=TPL3^.NXTPL;
     if FLAG then RELDIR[R1].FRSTPL:=RELDIR[R1].FRSTPL^.NXTPL
   until (not FLAG or (RELDIR[R1].FRSTPL=nil));
   if RELDIR[R1].FRSTPL<>nil then
    begin TPL1:=RELDIR[R1].FRSTPL;
     while TPL1<>nil do
      begin TPL2:=TPL1^.NXTPL;
       if TPL2<>nil then
        begin TPL3:=RELDIR[R2].FRSTPL;
         FLAG:=false;
         while not(FLAG or (TPL3=nil)) do
           if TPL3^.FIELD[1]=TPL2^.FIELD[1] then FLAG:=true
           else TPL3:=TPL3^.NXTPL;
         if FLAG then TPL1^.NXTPL:=TPL2^.NXTPL
         else TPL1:=TPL2
        end
       else TPL1:=TPL2
      end
    end;
   IREL:=IREL+1;
   GIVENAME;
   RELDIR[IREL].ATTD[1]:=RELDIR[R1].ATTD[1];
   RELDIR[IREL].FRSTPL:=RELDIR[R].FRSTPL;
   WRITE(RELDIR[IREL].RELNAMED:AL,' = DIFFERENCE OF ');
   WRITELN(RELDIR[R1].RELNAMED:AL,' AND ',RELDIR[R2].RELNAMED:AL);
   WRITELN('--------------':26,'---':15);
   WRITELN
  end;

procedure FINDNTH(R,A,N:integer;FLAG:boolean);
  var
   TPL1,TPL2:^TUPLE;
   I,J:integer;
  begin WRITE('Find the ',N:3,'th value of ');
   WRITELN(ATTDIR[A].ATTNAMED:AL,' in ',RELDIR[R].RELNAMED:AL);
   for I:=1 to 2 do WRITELN;
   J:=1;
   while RELDIR[R].ATTD[J]<>A do J:=J+1;
   for I:=1 to N do
    begin TPL1:=RELDIR[R].FRSTPL;
     while TPL1^.MARK do TPL1:=TPL1^.NXTPL;
     TPL2:=TPL1^.NXTPL;
     while TPL2<>nil do
      begin
       if not (TPL2^.MARK) then
        case FLAG of
         true:if TPL2^.FIELD[J]>TPL1^.FIELD[J] then TPL1:=TPL2;
         false:if TPL2^.FIELD[J]<TPL1^.FIELD[J] then TPL1:=TPL2
        end;
       TPL2:=TPL2^.NXTPL
      end;
     TPL1^.MARK:=true
    end;
   case ATTDIR[A].TYPEATT of
     IDENT:CONTAB[CN].VALI:=TPL1^.FIELD[J];
     INTNUMBER:CONTAB[CN].VALI:=TPL1^.FIELD[J];
     REALNUMBER:CONTAB[CN].VALR:=TPL1^.FIELD[J]
   end;
   TPL1:=RELDIR[R].FRSTPL;
   while TPL1<>nil do
    begin TPL1^.MARK:=false;
     TPL1:=TPL1^.NXTPL
    end
  end;
```

FIGURE 5.4 PROCEDURES SUBTRACT AND FINDNTH

5.4.3 Do Totalling:

This operation is invoked through a call to the procedure DOTOTAL(R), where R is the relation number in which totalling is to be done. The list of the same attributes is pointed at by ACTTAB.SATTS8 and the attribute of which the totalling has to be done is stored in ACTTAB.TATT. The list of tuples in R is traversed and for tuples which have the same values of attributes in the same list, the values of the appropriate field are summed up. IREL is incremented and RELDIR[IREL].FPSTPI is made to point at a new tuple which has the attribute values of attributes in the same list and the total of the attribute ACTTAB.TATT found above. The process is repeated for each new combination of values of same attributes found in R and new tuples are appended to the list in IREL. A listing of the procedure DOTOTAL is given in Fig. 5.5.

5.4.4 Sort:

This operation is invoked through a call to the procedure SORTOUT(R), where R is the relation which is to be sorted as per the information stored in ACTTAB.PSORT. A simple ripple sort methodology is adopted. The procedure sorts the relation only on one major field. A listing of the procedure SORTOUT is given in Fig. 5.6.

5.4.5 Count the Number of Tuples:

This operation is invoked through a call to the procedure FINDCOUNT(R), where R is the relation number of which the

```
procedure DOTOTAL(R:integer);
  var
    P:PTR1;
    TPL1,TPL2,TPL3:^TUPLE;
    I,J,K,JT:integer;
    JS:array[1..NOATTS] of integer;
    FLAG:boolean;
  begin IREL:=IREL+1; GIVENAME;
    WRITE('In ',RELDIR[R].RELNAMED:AL,' do totalling of ');
    WRITE(ATTDIR[ACTTAB.TATT].ATTNAMED:AL,' with same ');
    P:=ACTTAB.SATTS;
    while P<>nil do
      begin WRITE(ATTDIR[P^.ATTNOL].ATTNAMED:AL,' ');
        P:=P^.NEXTATT
      end;
    WRITELN; I:=1;
    while RELDIR[R].ATTD[I]<>0 do
      begin RELDIR[IREL].ATTD[I]:=RELDIR[R].ATTD[I];
        I:=I+1
      end;
    JT:=1;
    while RELDIR[R].ATTD[JT]<>ACTTAB.TATT do JT:=JT+1;
    P:=ACTTAB.SATTS; J:=0;
    while P<>nil do
      begin J:=J+1; I:=1;
        while RELDIR[R].ATTD[I]<>P^.ATTNOL do I:=I+1;
        JS[J]:=I; P:=P^.NEXTATT
      end;
    for I:=J+1 to NOATTS do JS[I]:=0;
    TPL1:=RELDIR[R].FRSTPL;
    if TPL1<>nil then
      begin NEW(TPL3); RELDIR[IREL].FRSTPL:=TPL3
      end;
    while TPL1<>nil do
      begin
        if TPL1^.MARK then
          begin TPL1^.MARK:=false; TPL1:=TPL1^.NXTPL
          end
        else
          begin TOTAL:=TPL1^.FIELD[JT]; TPL2:=TPL1^.NXTPL;
            while TPL2<>nil do
              begin
                if not(TPL2^.MARK) then
                  begin I:=1; K:=JS[I]; FLAG:=true;
                    while ((K<>0) and FLAG) do
                      begin
                        if TPL1^.FIELD[K]<>TPL2^.FIELD[K] then
                          FLAG:=false
                        else
                          begin I:=I+1; K:=JS[I]
                          end
                      end;
                    if FLAG then
                      begin TOTAL:=TOTAL+TPL2^.FIELD[JT];
                        TPL2^.MARK:=true
                      end
                  end;
                TPL2:=TPL2^.NXTPL
              end;
            TPL2:=TPL3; NEW(TPL3);
            TPL2^.NXTPL:=TPL3;
            I:=1; K:=JS[I];
            while K<>0 do
              begin TPL2^.FIELD[I]:=TPL1^.FIELD[K];
                I:=I+1; K:=JS[I]
              end;
            TPL2^.FIELD[I]:=TOTAL; TPL1:=TPL1^.NXTPL
          end
      end;
    TPL2^.NXTPL:=nil;
  end;
```

FIGURE 3.5 PROCEDURE DOTOTAL

```
procedure SORTOUT(R:integer);
  var
   SP1:^SORTNODE;
   I:integer;
   TPL1,TPL2,TPL3,TPL4:^TUPLE;
   FLIP:boolean;
  begin
   with RELDIR[R] do
    begin WRITE('Sort ',RELNAME:AL,' on ');
     SP1:=ACTTAB.PSORT;
     while SP1#nil do
      begin
       case SP1^.SORDER of
         UP   :WRITE(' ascending ',ATTDIR[SP1^.ATTNOS].ATTNAME:AL);
         DOWN:WRITE(' descending ',ATTDIR[SP1^.ATTNOS].ATTNAME:AL)
       end;
       SP1:=SP1^.NEXTSORT
      end;
     WRITELN;
     WRITELN;
     I:=1;
     SP1:=ACTTAB.PSORT;
     while ATTD[I]#SP1^.ATTNOS do I:=I+1;
     if FRSTPL#nil then
      begin TPL1:=FRSTPL^.NXTPL;
       if TPL1#nil then
       repeat FLIP:=false;
         TPL1:=FRSTPL^.NXTPL;
         case SP1^.SORDER of
           UP   :
             if FRSTPL^.FIELD[I]>TPL1^.FIELD[I] then FLIP:=true;
           DOWN:
             if FRSTPL^.FIELD[I]<TPL1^.FIELD[I] then FLIP:=true
         end;
         if FLIP then
          begin TPL2:=FRSTPL;
           FRSTPL:=TPL1;
           TPL2^.NXTPL:=TPL1^.NXTPL;
           TPL1^.NXTPL:=TPL2
          end
         else
          begin TPL1:=FRSTPL;
           TPL2:=TPL1^.NXTPL;
           TPL3:=TPL2^.NXTPL;
           if TPL3#nil then
            begin
             case SP1^.SORDER of
               UP:while not((TPL2^.FIELD[I]>TPL3^.FIELD[I])
                            or(TPL3=nil)) do
                  begin TPL1:=TPL2;
                   TPL2:=TPL3;
                   TPL3:=TPL3^.NXTPL
                  end;
               DOWN:while not((TPL2^.FIELD[I]<TPL3^.FIELD[I])
                              or(TPL3=nil)) do
                  begin TPL1:=TPL2;
                   TPL2:=TPL3;
                   TPL3:=TPL3^.NXTPL
                  end
             end;
             if TPL3=nil then
              begin TPL4:=TPL2;
               TPL2:=TPL1;
               TPL4^.NXTPL:=TPL3^.NXTPL;
               TPL3^.NXTPL:=TPL4;
               TPL1^.NXTPL:=TPL2;
               FLIP:=true
              end
            end
          end
       until not FLIP
      end
    end;
```

FIGURE 5.6 PROCEDURE SORTOUT

number of tuples is to be found. A variable 'KOUNT' is initially set to zero. The list of tuples in R is traversed and for each tuple encountered, the value of KOUNT is incremented by 1. The final value of KOUNT is the required count. A listing of the procedure FINDCOUNT is given in Fig. 5.7.

5.4.6 Truncate:

This operation is invoked through a call to the procedure LIMITED(R), where R is the number of the relation in which the tuples are to be limited to the number stored in ACTTAB.LIMNO. A listing of the procedure LIMITED is given in Fig. 5.7.

5.4.7 Remove Duplicates:

This operation is invoked through a call to the procedure RMVDPLCT(R), where R is the relation from which all the duplicate tuples are to be removed. The list of tuples is traversed sequentially and for each tuple, the remaining of the list is searched to find if there exists any more tuples with the same values in them. They are removed from the list if they exist. A listing of procedure RMVDPLCT is given in Fig. 5.7.

5.4.8 Union:

This operation is invoked through a call to the procedure UNION(R1,R2), where R1 and R2 are the two relations to be combined. The two relations have the same attributes. In this the list of tuples in R2 is appended to the list of tuples in R1 and the procedure RMVDPLCT is called to remove the duplicate

```
procedure FINDCOUNT(R:integer);
var
 I:integer;
 TPL1:^TUPLE;
begin TPL1:=RELDIR[R].FRSTPL;
 WRITE('Find the number of tuples in ',RELDIR[R].RELNAME:AL);
 WRITELN('and store in (COUNT).');
 WRITELN;
 I:=0;
 while TPL1<>nil do
  begin I:=I+1;
   TPL1:=TPL1^.NXTPL
  end;
 COUNT:=I
end;

procedure LIMITED(R:integer);
var
 I:integer;
 TPL1:^TUPLE;
begin TPL1:=RELDIR[R].FRSTPL;
 WRITE('Truncate ',RELDIR[R].RELNAME:AL,' keeping only ');
 WRITELN('the first ',ACTTAB.LIMNO:2,' tuples.');
 WRITELN;
 I:=ACTTAB.LIMNO;
 while I>1 do
  begin
   if TPL1<>nil then
    begin TPL1:=TPL1^.NXTPL;
     I:=I-1;
    end
  end;
 TPL1^.NXTPL:=nil
end;

procedure REMDUPLCT(R:integer);
var
 I,K:integer;
 FLAG:boolean;
 TPL1,TPL2,TPL3:^TUPLE;
begin TPL1:=RELDIR[R].FRSTPL;
 while TPL1<>nil do
  begin TPL2:=TPL1;
   TPL3:=TPL2^.NXTPL;
   while TPL3<>nil do
    begin I:=1;
     K:=RELDIR[R].ATTD[I];
     FLAG:=true;
     while (FLAG and(K<>0)) do
      begin
       if TPL1^.FIELD[I]<>TPL3^.FIELD[I] then FLAG:=false
       else
        begin I:=I+1;
         K:=RELDIR[R].ATTD[I]
        end
      end;
     if FLAG then
      begin TPL3:=TPL3^.NXTPL;
       TPL2^.NXTPL:=TPL3
      end
     else
      begin TPL2:=TPL3;
       TPL3:=TPL3^.NXTPL
      end
    end;
   TPL1:=TPL1^.NXTPL
  end
end;
```

FIGURE 5.7 PROCEDURES FINDCOUNT, LIMITED AND REMDUPLCT

tuples from the resulting list. IREL is incremented and RELDIR[IREL].FRSTPL is made to point to the first tuple of the new list. A listing of the procedure UNION is given in Fig. 5.8.

5.4.9 Intersect:

This operation is invoked through a call to the procedure INTERSECT(R1,(R2), where R1 and R2 are the two relations whose intersection has to be found. The two relations have the same attributes. The list of tuples in R1 is traversed and for each of the tuples, the list R2 is searched to find if the tuple is present in R2 also. If it is, then the tuple is appended to the list of tuples pointed at by RELDIR[IREL].FRSTPL where IREL has been incremented in the beginning of the procedure. A listing of the procedure INTERSECT is given in Fig. 5.9.

```
procedure UNION(R1,R2:integer);
    var
     I:integer;
     TPL1:^TUPLE;
    begin IREL:=IREL+1;
     GIVENAME;
     WRITE(RELDIR[IREL].RELNAMED:AL,' = UNION OF ');
     WRITELN(RELDIR[R1].RELNAMED:AL,' and ',RELDIR[R2].RELNAMED:AL);
     WRITELN('------ --',21,'---',15);
     WRITELN;
     I:=1;
     while RELDIR[R1].ATTD[I]<>0 do
      begin RELDIR[IREL].ATTD[I]:=RELDIR[R1].ATTD[I];
       I:=I+1
      end;
     TPL1:=RELDIR[R1].FRSTPL;
     if TPL1<>nil then
      begin RELDIR[IREL].FRSTPL:=TPL1;
       while TPL1^.NXTPL<>nil do TPL1:=TPL1^.NXTPL;
       TPL1^.NXTPL:=RELDIR[R2].FRSTPL;
       REMDPLCT(IREL)
      end
     else
      begin TPL1:=RELDIR[R1].FRSTPL;
       if TPL1<>nil then RELDIR[IREL].FRSTPL:=TPL1
       else RELDIR[IREL].FRSTPL:=nil
      end
    end;
```

FIGURE 5.6 [illegible]

```
procedure INTERSECT(R1,R2:integer);
    var
     I:integer;
     FLAG:boolean;
     TPL1,TPL2,TPL3:^TUPLE;
    begin IREL:=IREL+1;
     GIVENAME;
     WRITE(RELDIR[IREL].RELNAMED:AL,' = INTERSECTION OF ');
     WRITELN(RELDIR[R1].RELNAMED:AL,' and ',RELDIR[R2].RELNAMED:AL);
     WRITELN('------------ --':28,'---':15);
     WRITELN;
     I:=1;
     while RELDIR[R1].ATTD[I]#0 do
      begin RELDIR[IREL].ATTD[I]:=RELDIR[R1].ATTD[I];
       I:=I+1
      end;
     if((RELDIR[R1].FRSTPL=nil)or(RELDIR[R2].FRSTPL=nil)) then
       RELDIR[IREL].FRSTPL:=nil
     else
      begin
       repeat TPL3:=RELDIR[R2].FRSTPL;
         FLAG:=true;
         while(FLAG and(TPL3#nil)) do
          begin I:=1;
           while(FLAG and(RELDIR[R1].ATTD[I]#0)) do
            begin
             if TPL3^.FIELD[I]#RELDIR[R1].FRSTPL^.FIELD[I] then
               FLAG:=false
             else I:=I+1
            end;
           TPL3:=TPL3^.NXTPL
          end;
         if not FLAG then RELDIR[R1].FRSTPL:=RELDIR[R1].FRSTPL^.NXTPL
       until(FLAG or(RELDIR[R1].FRSTPL=nil));
       TPL1:=RELDIR[R1].FRSTPL;
       while TPL1#nil do
        begin TPL2:=TPL1^.NXTPL;
         if TPL2#nil then
          begin TPL3:=RELDIR[R2].FRSTPL;
           FLAG:=true;
           while(FLAG and(TPL3#nil)) do
            begin I:=1;
             while(FLAG and(RELDIR[R1].ATTD[I]#0)) do
              begin
               if TPL1^.FIELD[I]#TPL2^.FIELD[I] then
                 FLAG:=false
               else I:=I+1
              end;
             TPL3:=TPL3^.NXTPL
            end;
           if not FLAG then TPL1^.NXTPL:=TPL2^.NXTPL
           else TPL1:=TPL2
          end
         else TPL1:=TPL2
        end;
       RELDIR[IREL].FRSTPL:=RELDIR[R1].FRSTPL
      end
    end;
```

FIGURE 5.8 PROCEDURE INTERSECT

# CHAPTER VI

# CONCLUSION

## 6.1 Summary of the Work Done:

In this thesis we have suggested a new query language for information retrieval from a relational data base. We have seen that the language is simple and reasonably complete. The language is based on the concept of decision tables and does not involve more difficult concepts of mapping, recursion etc. It also does not require one to know 'predicate calculus' as does DSL ALPHA.

We have developed a system which processes queries in this language. We have first shown how the system converts statements of the query to relational algebra expressions and then how it applies the algebra operations on the relations in the system. A sample data base was chosen and several types of queries were run on it. The outputs of these have been shown.

The system is general enough in that it can read in any new data base and process queries on that data base. The only change required to be made in the system is that the values of NOATTS, NORELS and NORELSP have to be set to the number of attributes in the data base, the original number of relations in the data base and the total number of relations permitted i

the system respectively. This is done by the CONST declarations in the beginning of the program. Ofcourse, the relations and the attributes of the new data base have to be defined in files RELDEF and ATTDEF respectively.

The system has been extensively tested and, from the satisfactory results it produces, it can be asserted with reasonable confidence that the new language proposed in this thesis is convertible to algebraic operations which can in turn be applied on the relations in the data base.

## 6.2 Scope for Improvements:

In case of a complex data base, where two relations can be related to each other through more than one relation, the table COMREL could be made three dimensional, storing the list of all such common relations in the third dimension. In that case the user must be asked to define his environment before he states his query. During the process of object query generation, we look up the common number between the entries in the COMREL table and the entries in the array 'ENVIRONMENT'. A query would then look as follows -

```
QUERY(WORKSPACE)
ENVIRONMENT : relation names
CONDITION :  condition part
ACTION : action part;
```

Finally, the algorithms for implementing the algebraic operations, suggested in Chapter V, can be made more efficient by storing the relations as indexed sequential files. In fact, much more work needs to be done to achieve maximum efficiency in the implementation of these basic operations.(Ref. [12]).

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